# *Corrosion—The Industrial Parasite*

NATIONWIDE the fight rages against those insect pests that threaten our supplies of life's necessities. Farmer, clerk, laborer, the very government itself, is deeply concerned in the battle against boll weevil, tree borer and wheat rust. The services of the scientific men of the country are enlisted in this anti-famine army. Indeed, chemical engineer and chemist lead the van. The whole country is awake to the importance of eliminating the waste that menaces our existence.

But along another line our existence is also threatened. Industrial progress is necessary if profitable occupation is to be found for our ever-increasing millions. And square across the road of such progress lies the problem of finding materials of construction that will meet the service we demand of them and permit our industries to carry on without too great a burden of replacement. A battle on corrosion, as stern and unending as that now waged on weevil and borer, is vital to the future of industry and the nation.

\*    \*    \*    \*    \*

We would not in any way depreciate the splendid work that has been done on corrosion and corrosion resistance—nor would we withhold the credit due the development of many important materials of construction. Yet too many of us in the past have striven to utilize the best available material for a specific purpose rather than to concentrate our energies on the underlying reasons for the corrosion itself. Now, fortunately, fundamental study is well begun—the work is gathering momentum and enlisting many of the best research minds of the country. All of this has come with the slowly dawning realization that corrosion is a major problem of industry.

That this recognition has not come sooner is due to the very nature of the problem. Corrosion's wastage is often neglected simply because it does not appear on a separate ledger account. Its loss is charged to installation, to maintenance and repair, or, as is most often the case, is totally obscured in a blanket depreciation figure—mysteriously arrived at and sacredly guarded against analysis and revision. The neglect of corrosion was particularly true in the days when replacement and repair costs were relatively small. Then it scarcely mattered that depreciation was rapid. But with the increase in manufacturing efficiency, with the tendency toward standardization of process and machinery, the margin of profit has grown steadily less. Replacement and installation costs have assumed a greater importance. In many instances corrosion resistance has spelled the difference between profit and loss.

\*    \*    \*    \*    \*

This issue of *Chem. & Met.* presents a somewhat novel perspective of the corrosion problem. Practically all of the corrosion data heretofore collected measure in terms of confusing and widely varying units, either the resistance of particular metals and alloys to reagents or the converse of it, the action of a specific reagent on a number of metals and alloys. With this in mind, the staff of *Chem. & Met.* has constructed this issue on a frankly qualitative basis. More than a thousand engineers in various industries have been solicited for their opinions as to the best industrial practice from a corrosion-resistance standpoint. This information has been carefully sifted and interpreted in the form of twenty or more editorial summaries, focusing attention on the corrosion problems of the separate industries, the means adopted for their solution, and the present status of problems yet unsolved. In addition there are included pertinent data from two outstanding compilations by the American Society for Testing Materials and the National Research Council. The former tabulates the principal chemical and physical properties of seventy-five corrosion- and heat-resistant alloys of general manufacturing interest. The latter reviews recorded experience in the application of the pure metals most used in chemical engineering construction.

\*    \*    \*    \*    \*

This information is placed before you in the belief that it will be of service. The problems of other men in other industries invariably carry some suggestions of value to your own. We are glad to acknowledge our indebtedness and yours to the many contributors who have made this service possible.

# How the Petroleum Industry
## *is solving its*
# CORROSION PROBLEMS
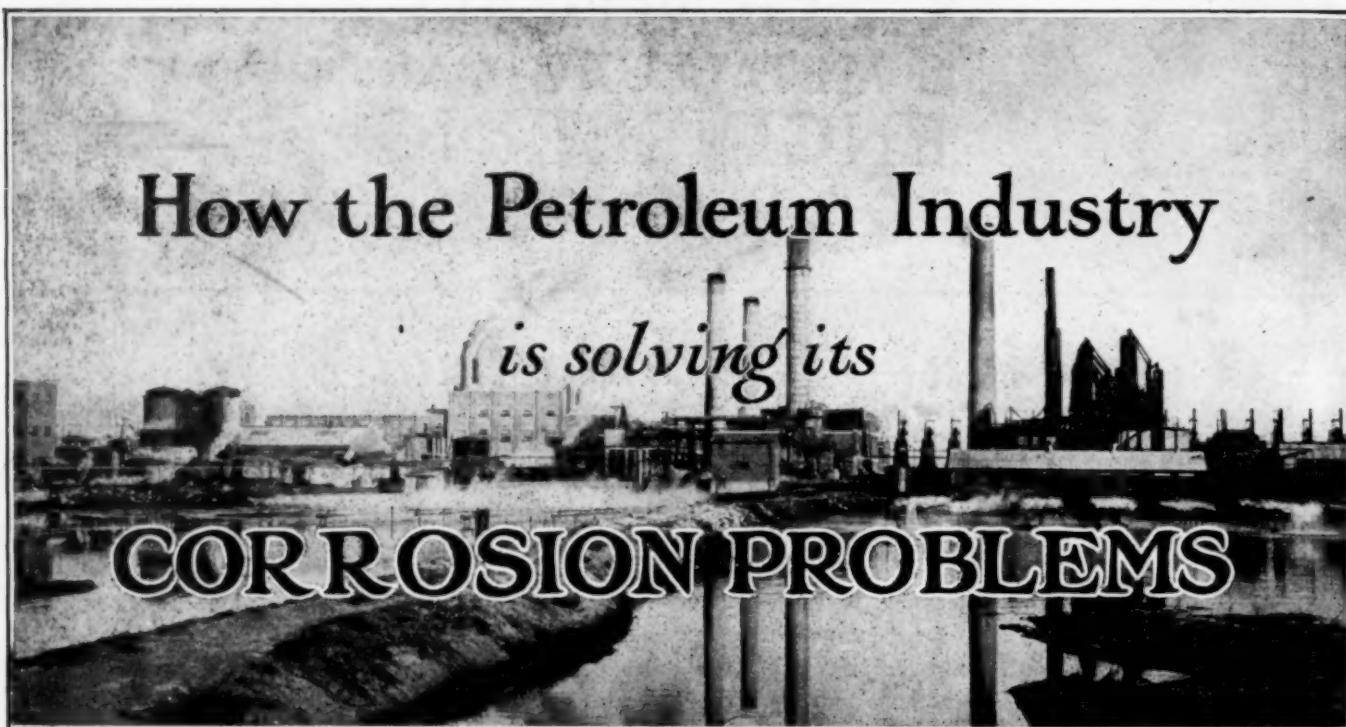
*An Editorial Summary Based on the Opinions of Representative
Technologists in Oil Production, Transportation and Refining*

CORROSION is the ever-present bête noire of the petroleum industry. Its first withering influence is felt even before the crude oil reaches the surface of the ground and its trail of destruction can be followed through every process in production, storage, transportation and refining. No one has ever attempted to evaluate in dollars and cents—if indeed that would be possible—the astounding toll that corrosion exacts each year from the petroleum industry. Certainly it is a figure that runs well into the millions, for it is made up not only of damage and deterioration to replaceable equipment, but is responsible for tremendous loss and wastage of an irreplaceable resource.

Believing that it would serve a useful purpose to bring together in an editorial summary a survey of the corrosion problems of the industry as well as the means by which they are being solved, the editors of *Chem. & Met.* have solicited, through the agency of a questionnaire, the views of more than a hundred representative petroleum technologists. It is on the basis of this information that the following summary has been prepared.

### OIL FIELD PROBLEMS

Because of the wide variation in the composition of crude oils, each presents its own corrosion problems and requires essential differences in construction and equipment. No one of the constituents of petroleum, however, is more detrimental than sulphur, which is of widest occurrence in quantities varying from less than a tenth of a per cent in Pennsylvania crude to 3 or 4 per cent or even higher in the Mexican oils. In some localities salt brines containing considerable quantities of magnesium chloride are associated with petroleum, and it is the hydrochloric acid resulting from the hydrolysis of this brine that presents a most serious corrosion problem.

When it is considered that the so-called "oil country goods" account for practically half the total production of tubular iron and steel in this country, some perspective is gained of the immense quantity of metal affected by corrosion in the oil fields. For the most part this material is unprotected even though under the most favorable conditions for corrosion.

The first metal to be attacked by the sulphur compounds and other corrosion in the crude oil is the well casing and tubing. There is practically no protection possible except by the use of better quality and heavier goods. The industry has recognized the gravity of this situation and important committees of oil men are working with the steel producers in the process of establishing higher standards of quality and workmanship for oil country goods. Specifications have existed in the past, to be sure, but not until recently has the problem of standardization been approached from the viewpoint of improving the specific conditions that have already resulted in appalling losses in the oil fields. A piece of casing, rushed across the country in the frenzy of flush production, attached to a string of casing or drill pipe extending 3,000 or 4,000 ft. below the surface, suddenly becomes literally a precious metal. Its failure, due perhaps to a defect such as is shown in Fig. 1, means a loss not only of a string of pipe worth perhaps $5,000 but it may actually mean the loss of the entire expenditure, say $50,000 to $100,000, on the almost completed drill hole. And in addition there is an even greater loss of oil production before the well can be completed. While corrosion is a contributing rather than casual factor in most failures of casing, the problem is nevertheless one of the most serious that the industry faces. It will not be solved until better materials are available and are used wisely and with greater care.

In many fields loose sand is brought to the surface with the oil, very much to the detriment of the pumps and valves as well as equipment in subsequent refining

processes. In such localities well screens or strainers are provided to exclude the sand. These are slotted covers of brass, bronze or galvanized steel that slip over the perforated end of the casing to prevent its clogging. In addition to the erosion by the sand these screens are subject to corrosion by the brine, oil and galvanic action set up between the two metals. Their failure and subsequent replacement mean costly fishing and loss of valuable oil production.

The ordinary steel storage tank for crude oil is subject to the action of no different corrosives than other oil-field equipment, yet serious damage is not uncommon, especially with high-sulphur oils. The vapors attack the inside of the tops of these tanks, which are usually the first parts to be affected. A fair degree of protection is obtained by the use of paint resistant to the action of the vapors. Corrosion difficulties are also reported with tank bottoms where water may collect under the oil, bringing with it dissolved sulphur compounds and the acid from the emulsified brines.

### SOIL CORROSION—THE OUTSTANDING PROBLEM

Probably there is no other problem in the oil industry that approaches in dollars-and-cents importance the corrosion of underground pipe. In addition to the 75,000 miles of main pipe lines that form a network extending over the entire country, there are thousands of buried pipe lines carrying oil, gas, steam and water in oil fields, refineries and distribution centers. All of these are subject to corrosion to a varying extent depending upon soil conditions, the metal used and the protective coverings provided.

Probably the alkaline soils of the West have given



Fig. 1—A Defective Well Casing That Was Responsible for a Costly Failure

A "double rolled scalp" resulting from threading at a joint where two pieces of pipe were rolled together.

most trouble to pipe lines, yet equally serious difficulties are encountered in damp, wet soils in the mid-continent and in the salty, acid marshes in certain districts along the Atlantic seaboard. Under these conditions some protective coating is absolutely essential. The method first developed in California and now generally used consists in painting the pipe with asphalt paint, pouring molten asphalt around it and finally wrapping it with specially prepared roofing paper or burlap. As pointed out by one technologist, however, "no dip or paint will permanently protect a pipe line against electrolysis or corrosion in wet soil." Furthermore, an incomplete coverage is usually worse than

none at all, in that it concentrates the corrosion on the relatively small exposed surface.

Concrete offers a more expensive and in some ways more desirable means of protecting a pipe line, yet it is not universally regarded as a complete solution for soil corrosion. It is not effective in wet soil and under any conditions must be carefully laid. Fig. 2 shows what can happen through careless construction.

Very often it is not economical to cover certain sizes of pipe, and furthermore there is a great deal of underground pipe left unprotected simply because it is regarded as temporary construction. This applies particularly to the so-called lessee lines, generally 2, 3 and 4-in. surface lines for gathering oil from producing leases. Usually no effort is made to protect them, although occasionally some attention is given to improving drainage conditions in order to keep the pipe as dry as possible.

Before leaving the subject of pipe line corrosion it
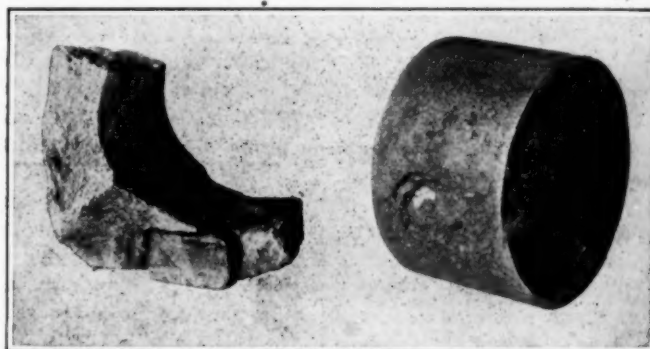


Fig. 2—Failure of a Pipe Line by Corrosion Due to Faulty Concrete Protection

The small wood block shown imbedded in concrete at left was presumably used to block up the pipe line while concrete was being poured. It was not removed and afforded an easy entrance for moisture and soil corrosives.

is only fair to call attention to the large amount of fundamental research and study being directed toward this subject through the excellent work of the U. S. Bureau of Standards, and of the committees of the American Society for Testing Materials and the American Petroleum Institute. These agencies are making important progress toward a solution of this outstanding problem.

### CORROSION IN THE REFINERY

It is safe to say that all of the characteristic corrosion problems of petroleum so far discussed are met in even more aggravated form in the refinery. Furthermore, there is a wide variety of serious problems typical of refining operations carried out in a highly corrosive atmosphere and involving corrosion by acids and alkalis, sea water, sulphur trioxide, ammonia and other corrosive liquids and gases. The skeleton flow sheet shown on pages 45 and 46, which was adapted from Bell's excellent book on "American Petroleum Refining," is indicative of only a part of the corrosion problems of the petroleum industry. The complete refinery carries on many operations not shown there, as for example, acid recovery, still gas absorption, etc.

One of the first as well as most severe instances of corrosion in the refinery is found in the condensing equipment for crude oil distillation. The condenser tubes often deteriorate very rapidly, for they are acted upon from the inside by sulphur compounds and hydrochloric acid in the oil and vapors, while the outside of the tubes is in contact with cooling water that often

contains many corrosive ingredients. In fact, along the seaboard salt water is used for practically all condensers and it brings with it the typical problems of sea-water corrosion such as the pitting of iron and steel, scale formation and accelerated electrolytic action. The effect is also seen on the condenser boxes, stay-bolts and tube supports.

The proper selection of the metal to be used for condenser tubes depends upon the character of the vapors condensed, the cooling water and, of course, the relative cost. In the approximate order of their usefulness considering availability and costs we find cast iron, commercially pure iron, steel, brass, wrought iron and galvanized iron or steel being used.

Brass is almost an ideal metal for condenser tubes under some conditions and its more extended use has been retarded principally by cost considerations. That its application has already assumed considerable proportions, however, is indicated by the fact that one large Eastern refinery reported the use in its plant of more than a million feet of brass, copper and bronze tubing of which 450,000 ft. was employed in condensers and heat exchangers. Brass condenser tubes have also been found most satisfactory in the distillation of crude oils containing any considerable quantity of magnesium chloride brine.

In connection with condenser tube corrosion the reader will find it worth while to review the several articles on the "Corrosion of Petroleum Refining Equipment," by R. R. Matthews and P. A. Crosby, of the Roxana Petroleum Corporation, which appeared in *Chem. & Met.*, vol. 22, No. 11, p. 491 (March 17, 1920); vol. 23, No. 23, p. 1122 (Dec. 8, 1920), and vol. 26, No. 24, p. 1119 (June 14, 1922). In their experience with a mid-continent oil high in emulsified brine serious cor-



Fig. 3—Iron and Steel Under Various Conditions of Corrosion
The wrought-iron strap or hoop was taken up in Burlington, N. J., where it had served for reinforcing a cypress wood pipe. It was laid in 1804 and was taken up in 1922 after 118 years of service. Note the bright, new metal appearance where polished. The other badly corroded pieces are staybolts and brace rods from condenser boxes subjected to salt water corrosion.

is not necessarily true if the crude oil is high in sulphur or other corrosive ingredients.

The corrosion of the shell type of stills most used for crude oil distillation is largely confined to the still bottoms, where water, brine and sludge accumulate and their corrosive action is increased on account of the heat. For this reason and in order to resist the accelerated oxidation at comparatively high temperatures, extra heavy plate of special still-bottom steel is generally specified. Periodically as these are burned out or become thinned by use they are replaced.

The increasing use of tube stills, in which the oil is circulated through heated tubes before passing to a
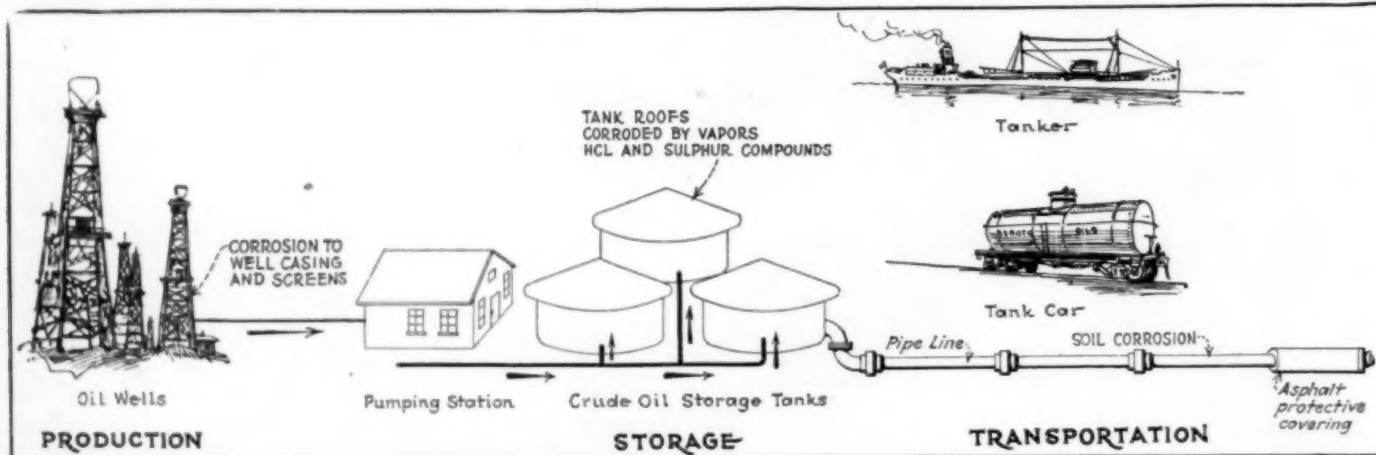


rosion due to hydrochloric acid was first observed in the pipe stills and later in the condenser and heat exchanger tubes. The former failed after 2½ years of service; the latter after about 1½ years. As a preventive measure ammonia was introduced into the vapor system; first the anhydrous and later the aqua ammonia was used. Corrosion was thus retarded and the life of the equipment, especially of the condensers, was greatly increased.

### Corrosion of Stills and Fittings

Reference has been made to the similarity in the corrosion problems of the condenser and the heat exchanger. The absence of cooling water in the latter generally means longer life for the equipment, yet this

shell, tank or tower system, has brought with it a number of characteristic corrosion problems. For the most part these are concerned with tube failures due to carbon deposits and to the corrosive action of sulphur compounds, moisture and brine associated with the oil.

It would be difficult to overemphasize the many serious effects directly traceable to the deposition of coke in the still tubes. Carbon is, of course, one of the natural products of cracking and its presence cannot be avoided. As it accumulates in the tubes, however, it decreases thermal transmission, making it necessary to heat the tubes to a higher temperature in order to force the distillation. The result is that as the coke continues to deposit there is intense local overheating, a so-called "hot patch" develops and frequently the tube
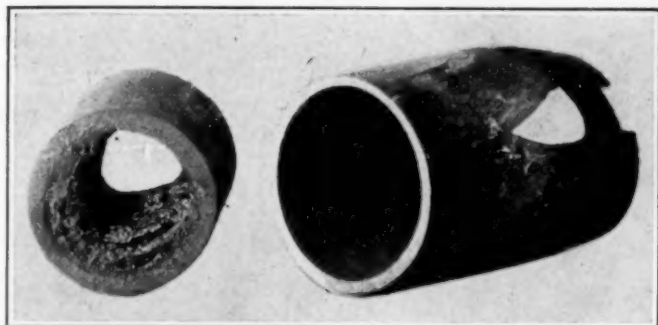
**Fig. 4—Coke Deposit in a Still Tube and One of Its Consequences**
The heavy accumulation of carbon, salt and sand in the tube at left resulted from distillation of a troublesome Mexican crude. The section at the right shows what a "hot patch" will do to a tube in a pressure still.

burns out. Another undesirable effect is carburization, or the penetration of carbon into the steel, thus weakening the tubes by embrittlement, with consequent scaling and deterioration.

By means of the calorizing process still tubes are given on both the inside and outside a protective surface of aluminum alloy that materially reduces corrosion difficulties. Because of the smooth inner surface of the tube and its film of aluminum oxide, it is claimed that the carbon does not adhere as firmly as is the case with a rougher steel surface.

When the tube stills are used for cracking, as is the case with several well-known processes, there is naturally an acceleration of corrosion as a result of the higher temperature of the oil (around 750 deg. F.) and the pressures, which are usually above 100 lb. per sq.in. and in certain processes may run as high as 500 to 750

lb. Yet we find some refiners reporting the apparent anomaly of less trouble with cracking than with crude stills. One of the principal reasons for this is the extra heavy construction by which the factor of safety is greatly increased, in order to take care of failures of any kind. Two-inch plate is commonly employed in the fabrication of pressure stills, while the reaction chambers in some cracking processes are in reality gun forgings.

The tube stills in certain cracking units represent a modification of the familiar B. & W. type of boiler in which the ends of the inclined tubes are rolled into expanded headers. Opposite the ends of the tubes in the headers are hand-holes required for convenient cleaning of the tubes. These holes are plugged in two ways: Either by means of a forged or cast plug threaded in from the outside or by the so-called key caps driven into place from the inside and held there by the pressure within the still. In either method, however, corrosion is a very serious problem, making replacement necessary at frequent intervals. Probably the most satisfactory metal for the threaded plugs is forged Monel metal. Plugs from this alloy appear to have longer life than from other materials of construction, although it is not uncommon to have to replace them in pressure stills after 2 to 4 months service. They are subject to a combination of corrosion and erosion resulting in a type of deterioration shown in Fig. 5.

Key caps are cupped from disks of rolled steel, although some economy has been demonstrated with calorized caps. In Fig. 6 are shown two key caps subjected to the same service in a cracking still of an Eastern refinery. The cap on the left is of plain steel and beyond the



**Flow Sheet of the Petroleum Industry, Showing the Principal Processes and Equipment in Which Corrosion Difficulties Are Encountered**
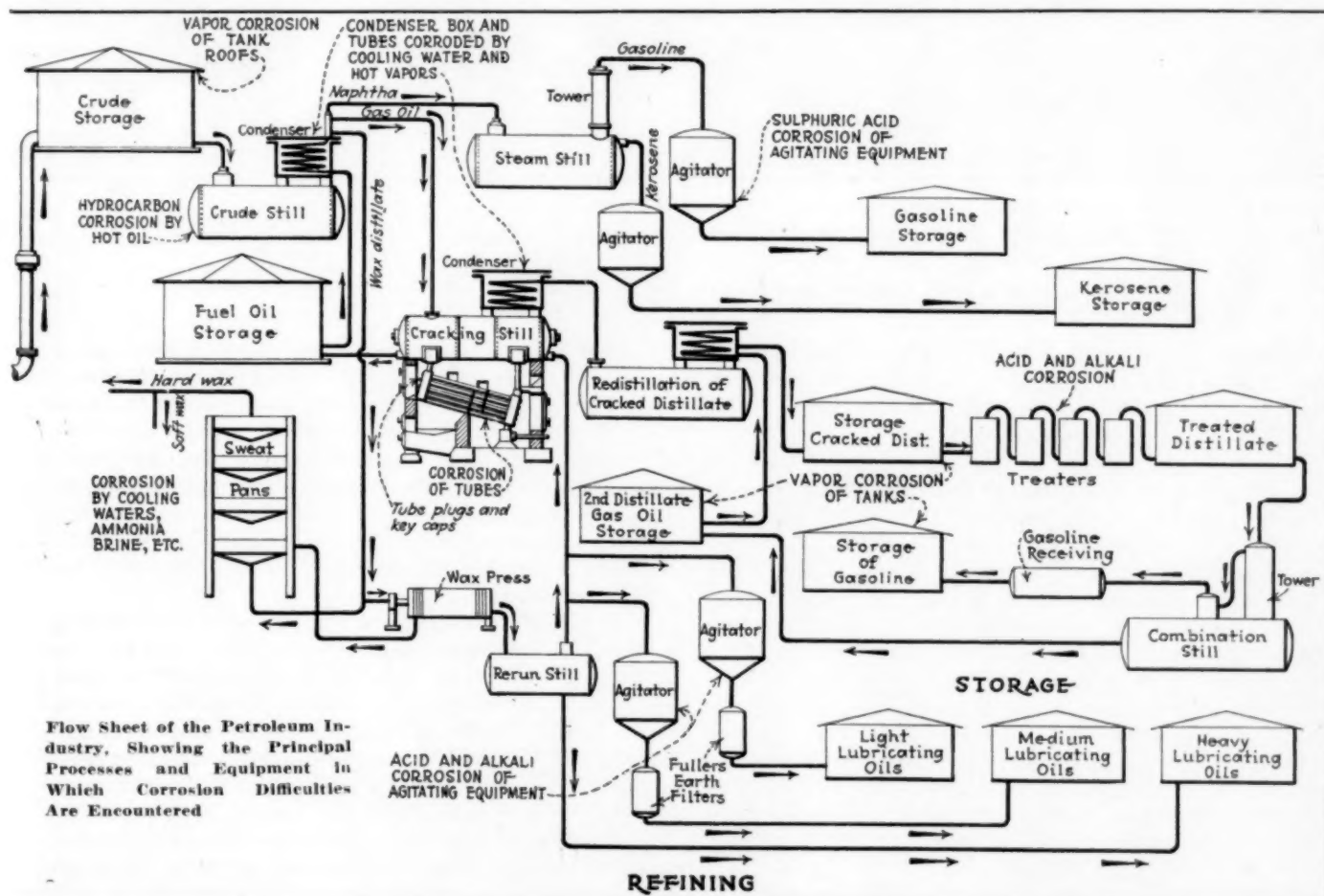
smooth band, where it was protected by the header, it shows the evidence of considerable corrosion. On the right is a calorized cap which shows practically no deterioration. A similar test in another refinery showed a loss after 74 runs of 3 grams per calorized cap as compared with 73 grams for the plain steel cap.

### Agitators and Chemical Treaters

The types of corrosion already discussed are more typical of petroleum than is the case of the problems involved in the chemical treatment of various distillates. Here sulphuric acid and caustic soda are the principal offenders, and while the results of long experience in the handling of these corrosives are available from other industries, they are still the source of considerable trouble. The agitator tanks in which the treatment is effected are of lead-lined steel, while Duriron, bronze and acid-resisting alloys are employed for most of the fittings. The dilute acid washings are ordinarily handled in lead-lined or brass piping.

Most agitators, particularly for naphtha and light distillates, are built with globe-type roofs provided with hatches to give ample relief in case of an explosion. The roofs are, however, subject to severe corrosion on account of acid vapors and in spite of protective coatings they are at times badly corroded.

Chemical treatment of gasoline and lighter distillates is often accomplished in the continuous treater, consisting of a series of tanks or towers through which the distillate passes and in which it is subjected to the action of the acid, soda and wash water in successive
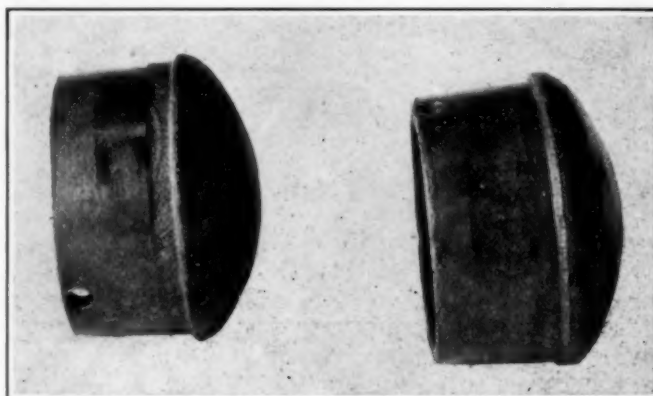


**Fig. 6—Two Key Caps Taken From Pressure Cracking Stills**

The bright band at the left shows protection by the header sheet, the remainder of the cap was exposed to corrosion. The calorized key cap at the right was subjected to exactly the same service and shows practically no corrosion.

ating units, chillers and filter presses, sweat pans, fullers earth filters and wax molding machines. The principal corrosives not met elsewhere in the refinery are ammonia and the cooling brines.

There are many miscellaneous instances of corrosion in the petroleum refinery that at least deserve brief mention here. Handling the aluminum sulphate solution for the Foamite fire-extinguishing system (with which practically every modern refinery is equipped) requires storage in wooden tanks provided with brass or copper tubing. Globe and gate valves represent further applications for brass, bronze and special acid-



**Fig. 5—Some Instances of Non-Ferrous Metal Corrosion in a Petroleum Refinery**

(*a*) Brass ball taken from a check valve in a hot tar pump. It shows a typical dezincification due to electrolytic corrosion. (*b*) An aluminum disk from a meter measuring cracked distillate. (*c*) A piece of brass pipe taken up after 7 or 8 years in contact with a 13 per cent solution of aluminum sulphate contained in an iron tank. Electrolytic action between the iron of the tank and either the Zn or Cu of the brass pipe resulted in dissolving out the zinc. Analysis showed the Zn content in the brass had been reduced from 40 per cent to about 3 per cent. (*d*) Cast Monel metal tube plug showing effect of corrosion and erosion due to contact with hot oil. The original thickness will be observed at the left of section shown at left.

treatments. Construction here is of a high-grade soft steel, which gives an exceptional resistance to corrosion except at the riveted joints. This fact has led to the general use of forge-welded tanks.

It is not possible here to present a detailed description of the several successful processes used for the recovery of the spent acid left after the chemical treatment of the different refined products. In all of the processes corrosion is a serious factor. Lead, often protected by acid-proof brick, is used for weak acid up to, say, 60 deg. Bé., while mild steel is more resistant than lead for the higher concentrations. In the older pan system a high quality of close-grained foundry iron was used for concentrating the acid—the average life of a pan being 30 to 60 days of service. In the patented system of the Chemical Construction Co. concentration is effected in acid-proof masonry towers, while the Simonson-Mantius system of the United Lead Co. concentrates the weak acid in a closed system under a comparatively high vacuum.

The equipment of the wax plant includes refriger-

resisting alloys. Pump rods are made of cast rolled brass and of Monel metal, which also is used to advantage in valve disks. Aluminum castings find application in the parts of some machines and in the disks of certain types of meters. Copper-bearing steel, although not widely employed at the present time, is generally regarded as more resistant to atmospheric corrosion than ordinary steel and at least one large refinery is giving its attention to this material for general construction use.

It would be unfair to conclude this summary without a word of acknowledgment and appreciation for the splendid co-operation from the technologists who have assisted in its preparation. As a survey it is incomplete, because it treats of an industry based on a raw material of widely varying characteristics and employing processes that cannot be standardized. As a review, however, it will have served its purpose if it can focus the attention of the other chemical engineering industries on the character of the many corrosion problems encountered in petroleum production and refining.

Minnesota By-Product Coke Co., St. Paul, Minn.

# Combating Corrosion in Gas Manufacture

*Experience Has Developed Many Ways for Delaying Corrosion in This Field,*
*but Certain Problems Are Yet Unsolved, While Others Are Only Partly Solved*

IN MAKING any general survey of the problems of corrosion met with in manufacturing coal products, it is first necessary to define clearly the limits within which the study is to be made. In this particular paper attention will be confined to the industries where fuel gas is the major product—that is, the byproduct coke plant, the coal-gas plant and the water-gas plant. These industries produce as byproducts coke, tar, light oil and its fractions, ammonia, ammonia sulphate and various products of less importance. The production of gas by the gas producer, generally confined to use in individual industrial plants, is attended with the same corrosion problems that are encountered in the gas works, but generally to a lesser degree, and hence will receive no special treatment. Natural gas, utilized as a fuel, presents the same corrosion problems that are encountered in the distribution of artificial gas and will therefore receive no separate consideration.

In making artificial gas there are three processes in general use—the byproduct coking process, the coal-gas process and the carburetted water-gas process. In some sections much gas is made by the oil-gas process. This is generally as an auxiliary to a supply of natural gas and the distribution problems are the same as those treated in the following discussion. In the manufacturing end, the oil-gas plant has corrosion problems generally similar to those encountered in the cracking of petroleum, and these will not be considered here. Atmospheric corrosion is not within the scope of the article, attention being confined to problems peculiar to the industry.

The coke-oven gas process is shown in outline by Fig. 1, in which only the principal steps are given. Fig. 2 is the same type of diagram for the coal-gas process, and Fig. 3 for the carburetted water-gas process. These three figures will serve to locate the various steps in the processes to which reference is made in the ensuing discussion of corrosion problems.

The material presented here has been gathered together from the experience of many of the largest and best organized plants in the United States and Canada. While it covers only the most important causes of corrosion met with in coal products manufacturing, the most usual means of attempting to overcome them and

a general consideration of some of the problems yet unsolved, it presents a fairly complete picture.

Due to the extremely complicated nature of many of the corrosive vapors and liquids encountered in coal products manufacturing, it is often impossible to spot the exact cause of the corrosion that occurs. In such cases the combative methods used are the result of experiment and do not as yet embody a final answer.

*General Steelwork of Plant.* There is much corrosion of structural materials at every plant carbonizing coal. Sheet metal housings and roofs, exposed steelwork, handrails and walkways are subject to rapid deterioration. Even concrete and the mortar of brickwork are attacked.

This corrosion is much greater than that ordinarily experienced from the atmosphere, because the carbonizing of coal releases various fumes that in the presence of moist air form weak acids and attack all corrodable surfaces with avidity. The coke-oven plant in particular, where the atmosphere is filled with clouds of steam bearing sulphur and other vapors from the quenching station, suffers from this type of corrosion.

The usual method of overcoming this condition is to keep the surfaces covered with a coat of acid-proof paint—usually one of a pitch or asphalt base. In repainting, great care should be taken to have the surface absolutely clean before the fresh coat of paint is applied and to place a coat of red lead under the tar paint. The most successful means that has come to attention so far is to use what is known as asbestos-protected metal for the sheet metal parts and to paint the other parts with a mixture of 90 per cent coal tar and 10 per cent portland cement. In this latter preparation the cement serves to make the coal tar neutral and to give it good spreading and holding qualities, while the tar is proof against the corrosive vapors.

The corrosion problems of this part of the plant are at present fairly well solved. A proper paint and eternal viligance with the cleaning brush and the painting brush is the best means that will probably ever be found for overcoming the corrosion occurring here.

*Coal and Coke Handling.* Sulphur in the coal and in the coke often is large enough in quantity to cause bad corrosion of all corrodable surfaces with which it comes

into contact. This corrosion does not seem to be as serious as that mentioned just above; but because certain metal surfaces cannot be covered, being kept exposed by action of coal or coke passing over them, it is difficult to eliminate. About the only method so far devised is to make these parts of copper-bearing steel. This is also used for adjacent structures, such as walks, railings, etc. This latter, if kept well painted by the same method as discussed above, can be fairly well protected; but care must be taken to keep the paint coat intact, as the abrasive dust that is present rapidly erodes it. In the case of the parts coming into contact with the coal or coke, these are subjected to abrasion to a high degree as well as to corrosion, and there seems no other alternative to frequent replacement. As much of the steel supports, etc., as can be should be covered
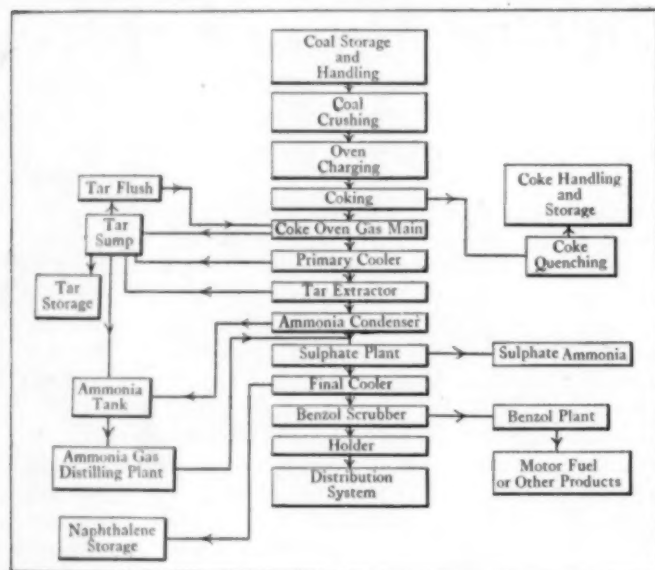


Fig. 1—Flow Sheet for Byproduct Coke Plant

with concrete, as that substance will do much to protect them and hence prolong their life.

*Metal Work at Ovens, Retorts and Generators.* Steel and cast-iron parts at ovens, retorts and generators come directly into contact with gas from the carbonizing chambers and also are subjected to high temperature. Because of these conditions there is some corrosion, enough to decrease markedly the life of these parts when compared with that of similar metals not subjected to such conditions. However, this does not seem to constitute a problem that worries the gas industry greatly. As a general thing, the life of these metal parts is longer than the life of the brickwork, etc., around the carbonizing chambers, and so the effects of their corrosion are not noticed. No attempt seems to have been made to eliminate corrosion at this point.

*Coke Quenching Station and Car.* The byproduct coke plant presents one of the most serious corrosion problems of the gas industry. This is incident to the quenching of the coke, in which operation the oven charge of extremely hot coke is pushed out into a transfer car and then transported to the quenching station, where it is drenched from above with large quantities of cold water. When this water strikes the coke, large quantities of steam are formed. Some of the steam dissociates and, in combination with the sulphur and other impurities in the coke, forms weak acid vapors. These rise with the cloud of steam and condense on all the cooler surfaces with which they come into contact.

The condition resulting is ideal for the promotion of corrosion, and rapid deterioration sets up in all the ordinary and possible materials of construction that are feasible on a cost basis except some of the bricks and tiles. These latter materials are generally used, in combination with acid-proofed concrete and well-painted metals where these must be used. The result, however, is not satisfactory and research must be undertaken to find proper materials.

Difficult as is the problem at the quenching station, the problem presented by the car in which the coke rests during quenching is more difficult. This car is subjected to alternate heating and cooling over a wide temperature range in addition to the same corrosive conditions as are met with at the quenching station. No solution of the problem has yet been made, and the only course seems to be to keep extra transfer cars and be constantly replacing parts.

*Collecting Mains and Gas Mains.* The gas is led away from its point of generation in collecting mains and gas mains. The collecting main, used in coal-gas and coke-oven plants, takes the gas from the various retorts or ovens and leads it to the gas main. Some trouble has been experienced with such mains, which are of steel plate construction, corroding, particularly at points where the gas enters. This is no doubt partly due to erosion. It can be partly overcome by keeping the gas temperature in the main as low as possible. Another partial remedy lies in lining the main with non-corrodable material. The corrosion in the main, however, is due to the sulphur, ammonia and cyanogen compounds in the gas and should be the subject of research if a proper material is to be found.
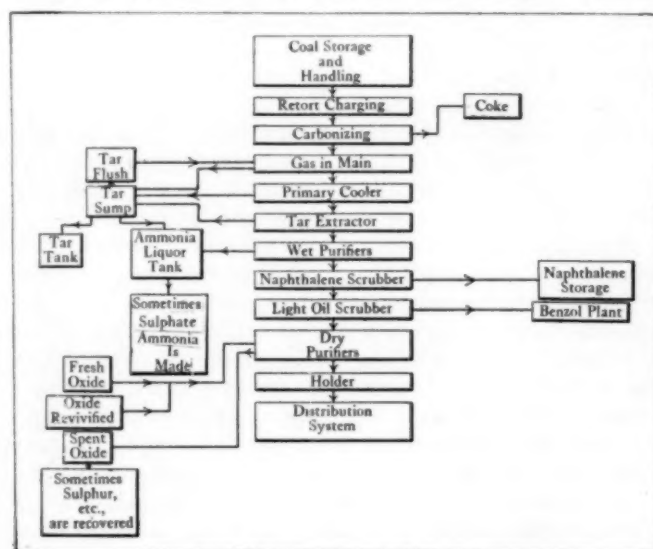


Fig. 2—Flow Sheet for Coal-Gas Plant

The gas mains also have similar corrosion, but less pronounced for two reasons. First, they are made of cast iron, which stands up in this service better; and second, the gases passing through them are cooler. However, some improvement is to be looked for here.

These mains are all subjected to corrosion on the outside because of the corrosive vapors in the atmosphere coming from the ovens and the quenching station. The solution here is again proper and careful use of protective paints.

*Gas Cooling and Condensing.* As soon as possible after the gases leave the generating chambers, they are cooled as near as possible to atmospheric tem-

perature and a large part of the tar and ammonia liquor is condensed and separated out. Corrosion on the gas side of the equipment used here does not seem to give much trouble, because the gas is cool and most of the corrosive elements are condensed out. There is some corrosion on this gas side, however, but it seems to have received little attention because of the trouble on the water side.

Corrosion on the water side of these coolers and condensers is mostly due to dissolved oxygen and organic acids in the water. One way to do away with this trouble is to use the Doherty Washer-Cooler or similar system of purification, which experiences much less corrosion than the closed condenser equipment. Another, and perhaps the best method, is to purify
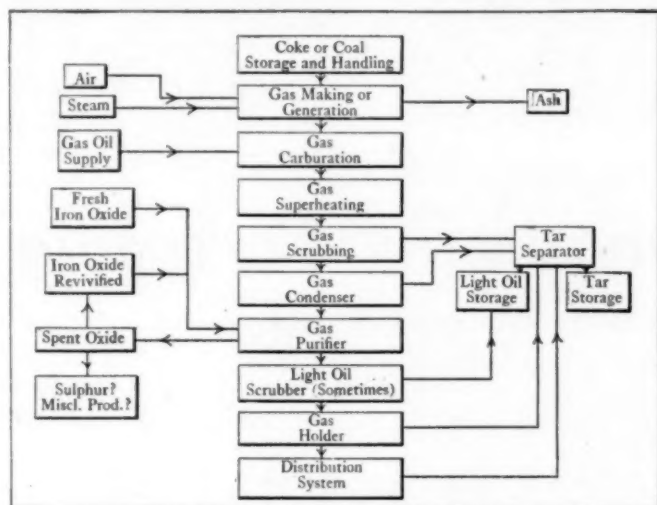


Fig. 3—Flow Sheet for Water-Gas Plant

the water used. This can be simply done by removing oxygen with an iron-filing filter and neutralizing the acids with lime treatment. A full description of this method is given in an article by L. E. Jackson, in *Chem. & Met.*, Jan. 11, 1922. In some other cases, open type condensers and washers of the grid filled tower design are used, and in these the condensing is accomplished by cool weak ammonia liquor. This latter system does much to lessen the corrosion and would be more often used if the towers were easier to clean.

If it is desired to retain the closed type countercurrent condenser and cooler—this being a good piece of apparatus from the operating standpoint—it is possible, in addition to purifying the water, to use tubes or plates of alloy metal. In this way the corrosion can be reduced to an almost negligible amount. It will be necessary, along this line, to do some additional research, but the pioneer work has already been done by metallurgists in the power plant field.

*Ammonia Removal.* In removing ammonia from the gas and also in making strong ammonia liquor and ammonia sulphate—semi-finished and finished products—trouble is experienced from the fact that ammonia attacks both steel and cast iron. The ammonia stills, used in connection with the ordinary ammonia sulphate process, are generally made of cast iron, and these stand up fairly well. But pipe, fittings, valves, dephlegmators and other equipment used cannot be of iron or steel.

There are three metals that can be successfully used, however. These are lead, special bronzes and aluminum. The lead is used for parts, linings, etc., at the ammonia sulphate plant. The saturator is lined

with lead. This will stand up under the corrosive action of both the sulphuric acid and the ammonia. Sulphate centrifugals have baskets of bronze or Monel metal and other parts are lead lined. In the ammonia still room, valves, fittings and pipe may be either lead-lined or of aluminum. The aluminum used should not be pure, as that material is too soft. The best metal is pure aluminum alloyed with 8 per cent of silicon.

It may be said that the problems of ammonia handling are fairly well solved and that, with care, there should be little trouble from corrosion from this source.

*Dry Purification.* Both coal gas and water gas must have the sulphur and cyanogen content removed before the gas can be distributed to the consumer. Although there are at present some new methods being used for this purpose, the usual method employed is to pass the gas through beds of hydrated ferric oxide. The sulphur and cyanogen join in chemical combination with the iron and the gas is thus purified. Incidental to this purification and to the revivification of the spent oxide there is corrosion of the steelwork used in construction. Here the remedy is to keep the surface freshly and thoroughly painted—red lead first, and on top of that some acid-proof tar, pitch or asphalt paint.

*Light Oil or Benzol Stripping.* Since the introduction of benzol motor fuel, it is becoming customary for the gas plant to recover as much of the light oil from the gas as possible. The light oil is then distilled and the lighter part is sold as motor fuel for admixture with gasoline, while the heavier parts are combined with the fractions from tar distillation for use in the coal-tar chemical industry.

The light oil is usually removed by absorption in straw oil or wash oil—a petroleum product—in tall scrubbing towers filled with wooden grids. The saturated wash oil is then distilled and most of the light oil removed. This light oil is washed with sulphuric acid in an agitator to take out the impurities and then neutralized with caustic. The neutralized acid is then fractionated to separate the motor fuel, etc.

With proper care and control the corrosion problems of this part of the plant are not great. The agitator in which the light oil is washed with $H_2SO_4$ and then neutralized must be of proper construction to withstand corrosion, and lead linings and Duriron parts where lead lining is not possible solve this problem. If neutralization of the light oil is not thorough, corrosion will occur beyond this agitator and it is often the practice to add a small amount of NaOH to the charge in the fractionating still to prevent corrosion of the column and the dephlegmator.

Water-cooled tubular condensers and coolers are used in benzol plant practice. The same problems of corrosion that are encountered in gas cooling and condensation—on the water side—occur, and the remedies should be the same. A gas plant cursed with a supply of corrosive cooling water is unfortunate and must often go to considerable expense in purifying this water if frequent replacements of cooling pipes and condenser tubes are not to be made.

*The Holder.* The inside of a gas holder should not be subjected to any serious corrosive conditions if the gas purification has been properly carried out. The parts exposed to the outside air meet the same corrosive atmosphere as does the other steelwork of a gas plant, although generally to a less extent because of location. For this reason the same methods of painting must be followed, eternal vigilance being the price that must

be paid if the holder is to be kept in good condition.

*Distribution System.* The mains in which gas is distributed are made of cast iron, wrought iron or steel. All of these materials are subject to soil corrosion if buried without some method of protection. Also, stray electric currents passing through the earth are likely to cause serious electrolysis. These currents should be carefully sought and eliminated at the source where possible. It is good practice to tie in the pipe lines to the negative bus of a power substation, in order to minimize the effect of stray currents.

Protection against soil corrosion generally consists in first cleaning the pipe with a wire brush, then painting with two coats of red lead in boiled linseed oil and finishing, after touching up with red lead any scratches that occurred in laying the pipe, with gilsonite or asphalt paint. According to one system, the pipe is wrapped—over the above-mentioned paint—with a spiral winding of heavy roofing paper saturated with hot liquid asphalt. Another system uses an outside coat of petrolastic cement, the pipe being rolled in sawdust while the cement is still hot and sticky.

The whole problem of corrosion from soil and from stray currents has not yet been solved. The industry is working on this problem now, particularly in California, and would welcome the help of all research bodies able to co-operate.

*Summary.* The foregoing discussion has hit only the high spots of the corrosion problems in the gas-making industry. There are a multiplicity of other problems not mentioned, small perhaps individually, but really formidable when viewed in the aggregate. Gradually these are being solved in an empirical manner. But if the process is not to be dragged out over a weary length of years, scientific methods must be applied—methods as scientific as those used in the operation of the plants. Only in this way can the great burden of replacement costs be lifted from the industry and the worry and waste that are now prevalent be finally eliminated.

# Fertilizer Industry Conquering Corrosion

### A Survey of Industrial Practice in the Production of Acid Phosphate, the Largest Constituent of Commercial Fertilizer

IN THE fertilizer industry there are scores of different products that are made by as many processes and that become ingredients of commercial fertilizer. These ingredients contain one or more of the three principal plant foods—phosphate, nitrogen and potash. It would be impossible and undesirable to go into the manufacture of all of these products. Many can be eliminated because the corrosion problems are negligible; still others because of the very special nature of the problems and their limited industrial importance.

Of the two most important products from an industrial standpoint, acid phosphate will be discussed in this section, whereas the corrosion problems connected with the recovery of ammonium sulphate as a byproduct from coke production are treated under that section heading. Acid phosphate is by far the largest single item in fertilizer manufacture. In 1923 more than 3,000,000 tons of acid phosphate was sold, as against 6,647,000 tons of fertilizer consumed during the same period. This naturally does not mean that 45 per cent of fertilizer is acid phosphate, as the two figures are not definitely comparable. It will, however, serve to emphasize the relative importance of acid phosphate in the fertilizer industry.

Acid phosphate is produced by treating high-grade phosphate rock (about 75 per cent calcium phosphate) with 52 deg. Bé. sulphuric acid (about 66 per cent $H_2SO_4$). The hot reaction mass is dropped into a "hot den" or reaction chamber, where it sets and must be removed with pick and shovel or (now more generally) by mechanical shovels. It is then stored in piles and shipped either as ground, screened acid phosphate or, after mixing with other ingredients, as mixed fertilizer. A troublesome byproduct of the reaction is the hydrofluoric acid that is evolved in the reaction pans and hot dens by the action of acid on fluorides contained in the original rock. The steps in the process of manufacture can be followed on the accompanying diagram, which will also serve as an aid in locating the corrosion problems.

Perhaps the first corrosion problem to occur to the average operating man would be the pipe used for transporting the dilute acid from the sulphuric acid plant to the acid phosphate plants. As a matter of fact this is not a serious problem. Ordinary lead pipe has been found to be satisfactory, in a vast majority of cases lasting from 5 to 15 years. Some exceptions have been noted. Where 60 deg. Bé. acid is brought from the towers to a mixing room and there diluted to 52 deg. Bé. the life of the lead pipe used for the more dilute ranges from 1 to 5 years, whereas the life of the strong acid pipe is from 8 to 15 years. This is of course to be expected, but it may emphasize the wisdom of making the long acid carries with strong acid.

Valves on the acid line are more of a problem. Duriron in all cases where it was used proved most satisfactory from a corrosion standpoint, but the valves were quite brittle and unless they were in continuous use they became frozen and broke when any attempt to reclaim them was made. Lead valves also wear out much more rapidly than the pipe, but usually last one or two seasons. (Parenthetically it may be noted that acid phosphate is produced frequently in a season of 150 days, though the tendency is in the direction of more storage space and all-year-round production.)

The second major corrosion problem in acid phosphate manufacture is the mixing pan—the apparatus in which the phosphate rock and sulphuric acid are brought together. Several different makes of pans are in use. In general they are shallow pans of cast iron or cast iron and steel with heavy plow stirrers capable of turning over a thick paste and a large plug-seat bottom discharge. The cast-iron parts of the equipment last from 5 to 12 years depending on conditions and continuity of operation. Frequently steel bottoms have to be renewed within 2 years and it is fairly general ex-

perience that the steel parts do not stand up for more than 3 or 4 years. Plow points are frequently a source of trouble. They must be renewed sometimes within weeks and seldom will they last over one season of 150 days. The difficulty lies not only in the corrosive action to which the points are subject but to the rapidly hardening mass that must be stirred. Each run lasts but a very few minutes (from 2 to 6 depending on temperature, concentration, etc.), and the consistency changes rapidly from fluid through light paste to a heavy plasterlike mix. Sometimes it will set solid in the mixer and will have to be chipped out. The plug seat is also worn rapidly by corrosive and abrasive action.

One random observation seemed of considerable interest. Corrosion had been markedly more rapid in the mixing pan since sulphur had replaced pyrites as a source of sulphuric acid. It was suggested that the small percentage of arsenic in the pyrites acid retarded the corrosion of iron. It would be interesting to know whether the observation recorded above has any or wide confirmation in industrial practice.

The next point of interest is the "hot den," or chamber into which the reacting mass is discharged from the mixing pan. The material stays in the hot den from a few hours to 24, when the main reaction is nearly over. It is then removed to a cold den or to a preliminary storage pile and finally moved again in from a few days to a week to final storage. All of this han-

dling is to prevent a hard cement-like setting of the acid phosphate. There are two general types of dens: The older type is a wooden tank or silo lined with brick. These dens are quite satisfactory and many are still in service after 15 years, the usual life being 10 to 12 years. The brick linings must be cared for, wall cracks cleaned and cemented periodically, and occasionally relining is necessary, usually every 6 years. The newer type of hot den is of reinforced concrete. This material "could not possibly be used for hot dens"—until some adventurous spirit tried it. Now nearly every new plant has reinforced concrete hot dens. Some instances have been noted of deterioration, but usually this is attributed to other causes than corrosion. By far the larger number leave a coating of acid phosphate on the walls of the den, thus effectively preventing further action. The life of concrete hot dens appears to be without present definite limit.

One more problem connected with the hot den is the cover, which is frequently made of wood and lasts anywhere from 6 months to 3 or 4 years.

The ventilating ducts from the hot dens also present a difficult problem. As the effluent gases contain large quantities of hydrofluoric acid, it is apparent that wood must have suggested itself early in the game. Few producers use anything else. One clings to terra cotta sewer pipe that has lasted him for 15 years, but several others find wood superior in comparative tests. Another uses concrete ducts that have already lasted for 5 years. Some of the wooden installations must be replaced in 1 or 2 or 3 years and few last 6 years without replacement. Oftentimes the nails or bands are the first things to give way and usually renailing is necessary every year. Probably the most satisfactory duct is wood nailed with galvanized nails and painted with asphalt base paint. Still another part of the same system is a subject for anti-corrosion thought. It is the exhaust fan used on the hot dens. Many different metals and alloys have been tried with varying results. Probably the best at present is a fan with wooden blades and housing and cast-iron supports and frames for the blades. These gases are the cause of general corrosion around an acid phosphate plant. They corrode metals used in building construction, pipe lines, etc. Especially is this true when the plant is located near the seashore. The most effective protection against this corrosion is annual painting with tar or asphalt. This is made more effective, as described in another section of this issue, by mixing with about 10 per cent cement. Other paints are in general not so effective as the inert organic compounds of coal tar.

There is further some wear on mills and screens used in conditioning the acid phosphate for shipment or in mixing it with other ingredients to form mixed fertilizer. Various types of mills are used, cage mills, Kent mills, swing hammer mills. In every case the corrosion deterioration is negligible and the mills have no more frequent repair cycle than do mills on other kinds of service. Some parts wear out more rapidly than others and there is occasional fracture of some mill part due to tramp iron. The same story obtains on screens, though the wire has a comparatively short life, less because of corrosion than because of the mechanical wear or because of tearing due to iron. Many have expressed a decided preference for vibrating screens, as they give cleaner, more perfect operation. Various metals have been used in the screens proper, iron, galvanized iron, brass, special bronzes and doubtless others. Almost universally they last a year or a season or less.
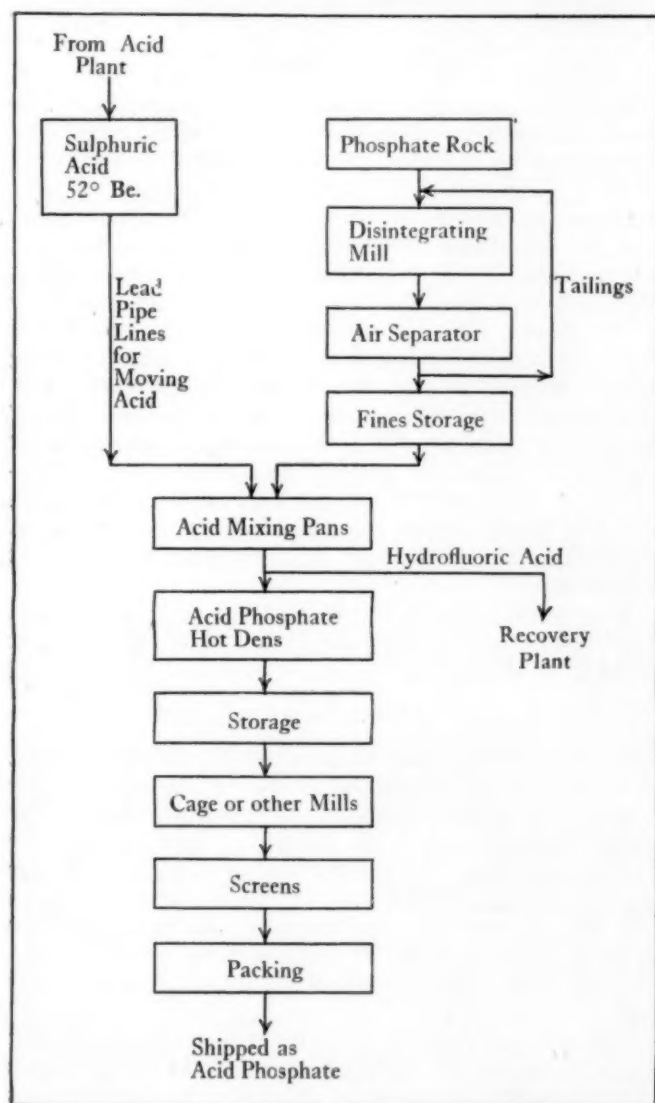


**Flow Sheet of Process for Manufacture of Acid Phosphate**

# How the Wood Distiller Dodges Corrosion

### *Action of Hot Acetic Acid Solutions and Vapors Makes It Necessary to Use Copper and Wood for Many of the Operations*

CORROSION in the hardwood distilling industry may be attributed mainly to the action of the hot dilute acetic acid in the pyroligneous liquor. After this acid has been properly neutralized, most of the trouble disappears. Previous to this step, however, the free acid has passed through more than half of the crude plant operations and its solutions and vapors have caused considerable corrosive action. In order to understand better the points at which corrosion problems occur, the following brief outline of the general processes involved in the destructive distillation of wood is given, and reference should also be made to the accompanying flow sheet. Data on the specific problems have been obtained through the generous co-operation of men in the industry, equipment manufacturers and investigators in close touch with conditions throughout the field.

### PROCESSES IN DESTRUCTIVE DISTILLATION

Air-dried cordwood in 52-in. lengths is loaded on steel cars with slatted ends and sides. The loaded cars are then run into large steel-plate oven retorts, the doors are sealed, and heat is applied to the outside of the retort. Destructive distillation proceeds for about 24 hours, the gases and vapors passing from the retort to tubular condensers that separate the condensate from the fixed or non-condensable gases. These gases contain a considerable proportion of combustibles and are burned under the retorts or the boilers.

When all of the volatile material has been removed from the wood, the cars of hot charcoal are drawn from the retort into a cooler of similar construction except that it is made of thinner steel plates and has a dirt floor. The doors are sealed air tight and the charcoal is allowed to cool for 24 hours. It then goes to a second cooler, where it also remains 24 hours. It must then remain in the open air for 48 hours before being loaded into cars, and the cars must be held 12 hours before shipment. These precautions are necessary in order to prevent fires in transit.

The condensate or crude liquid product of the distillation flows through a series of wooden settling tanks in which most of the tar settles out and runs to a wooden storage tank. The tar contains appreciable amounts of methanol and acetic acid, and these are recovered by steam distillation in a wooden still. The acid-free tar is used mainly for fuel.

The liquid condensate remaining after the separation of the tar is referred to as crude pyroligneous acid. It contains acetic acid and methanol, with small quantities of numerous other compounds. It also contains a certain amount of tar in solution, which must be removed in order to obtain a light-colored acetate of lime. Upon heating in a copper still or in a copper triple-effect evaporator, the tar remains behind, while the other products pass over into the distillate. This distillate is mixed with the solution of acid and alcohol recovered from the settled tar and the combined solution is neutralized in wooden tanks with milk of lime. The latter combines with the acetic acid to form non-volatile calcium acetate so that the methanol and other volatile products can be separated by distillation. From this point on, as noted above, there is very little trouble due to corrosion.

There are various methods of working up the products. The alcohol may be removed by distillation in an iron still, commonly called a lime-lee still, giving a weak alcohol, which is then concentrated to about 82 per cent strength in a separate column still, or a continuous column still may be used to give the strong alcohol by a single treatment.

In either case the residue in the still is a solution of calcium acetate. This solution may be concentrated by evaporating in open steam-jacketed pans, the resulting acetate mud being spread on drying floors above the retort oven. Multiple effect evaporators may also be used in conjunction with roll driers and wire belt driers.

As the production of acetic acid from acetate of lime is so frequently carried out at chemical plants, this final product has been treated separately elsewhere in this issue.

### RETORT OVENS

The first point at which corrosion occurs is in the ovens themselves. These are usually made of riveted ⅜-in. flange steel plates, and the standard 10-cord oven is 56 ft. long, 6 ft. 3 in. wide and 8 ft. 4 in. high. The ovens are usually set in pairs and because of the expansion are not placed directly upon the brick setting, but are suspended from steel cross-beams. The flues are so arranged that heat reaches the top, bottom and sides of the ovens. As the cast-iron doors are not heated from the outside condensation would take place, causing serious corrosion unless special precautions were taken. It is usual to provide storm doors for the purpose of preventing condensation and consequent corrosion at this point. There is also an opportunity for condensation in the cast-iron nozzles that conduct the distillation products from the retorts to the condensers. Heavy lagging is effective in preventing corrosion at this point.

The average life of the ovens is from 3 to 12 years. The coolers have a much longer life, and the cars last from 12 to 20 years.

### CONDENSERS

Condensers are used at many points in the process, but construction is fairly uniform. A series of copper tubes connects two chambers, also made of copper. The upper chamber, called the hood, has an inlet pipe for the vapors, while the lower chamber has an outlet for condensate, and in the case of the retort condenser a gas trap to separate the non-condensable gases. The whole condenser is set in a cylindrical water trough, the water level being about 6 in. above the upper tube plate.

The most serious corrosion takes place down the first 10 or 12 in. on the inside surface of the copper tubes of the retort condensers. Here the hot acid vapors

(approximately 600 deg. F.) coming from the retorts strike first and are condensed. Likewise the vapor hoods above the tubes on the retort condensers are subject to corrosion at the level of the condenser water, which as noted comes up above the head of the condenser about 6 in. on the hood.

It is the general practice on retort condensers to insert thimbles in the top of the condenser tubes. These thimbles are short lengths of copper tubing (10 to 12 in. long) flanged at the top to protect the end of



**Hardwood Distillation Flowsheet**

the condenser tubes and are tight fit to protect the inside surface of the condenser tubing where the corrosion is greatest.

The condensers are also interchangeable so that it is possible to invert them, equalizing the corrosion at both ends. When the ends are interchanged, the thimbles are also taken out and changed. It is the practice in some plants to invert the condenser after about 5 years of service, again after another 5 years, and then make one more change, obtaining from 13 to 15 years service from the condenser tubes. Condenser tubes have also been built with a heavier gage wall at the ends, thus eliminating the use of thimbles, and have given good service. The hoods on the condensers can be patched and made to last 20 years.

The vapors from the tar stills are particularly corrosive and the condensers on these stills corrode much more rapidly than those on the primary copper stills, although the composition of the vapors is quite similar.

It is not known just why the vapors at this point should be so corrosive.

Condensers on the primary copper stills and likewise the hoods corrode very slowly and have a comparatively long life. Corrosion in the methanol and lime still condensers is negligible.

## STILLS

Steam distillation of the settled tar for the recovery of acetic acid and methanol gives rise to the most serious corrosion problems in connection with the stills. The corrosive effect of the tar still vapors upon the condensers has been noted above. The action of the still contents themselves upon copper is so marked that wooden stills are commonly used with all the inconvenience and trouble that this kind of apparatus causes. The stills are usually built of either cypress or sound white pine and have a life of about 6 years. The copper head commonly used with these stills is apparently one of the most corroded pieces of equipment in a wood-distillation plant.

The primary stills for distilling the crude pyroligneous acid are made of copper and give satisfactory service. When triple effect evaporators are used to eliminate the tar, it is often necessary to replace the tubes every 2 or 3 years, and some trouble may occasionally arise through fouling of the tubes with tar.

Methanol and lime stills are of steel and are subject to practically no corrosion provided the acid liquor is not underneutralized. If such is the case, corrosion occurs at the boiling line of the liquid. Where corrosion takes place at this point, the stills are easily patched, thus giving longer service.

## PIPE LINES

There is a slight corrosive action on the copper lines carrying weak acid liquor, but replacements are few. All the liquid passing through these lines is cold with the exception of that in the dump-lines from the stills.

The non-condensable gases passing from the retort condensers to the main gas lines are somewhat corrosive, and copper, tile or even wood is used to carry them. When made of copper and well drained, the gas lines show little corrosion. Wrought-iron pipe used for this purpose has a life of about 4 years. The main gas lines are of cast iron and in one plant there is a record of such a pipe being used 22 years and still in good serviceable condition.

## TANKS

The tar contains free acids that are more or less corrosive and in general all vessels for handling and storing tar are made of wood. Wooden tanks are also used wherever it is necessary to settle, treat or store the acid liquor. Neutralization with lime takes place in wooden tubs provided with wooden agitators.

## SUMMARY

In combating the corrosion problems in the hardwood distillation industry, which are due mainly to dilute acetic acid, hot or cold, in solution or as vapor, copper and wood have been found most effective. While the wooden tar stills are somewhat inconvenient, it might be said that the most important corrosion problems of the industry have been met in a satisfactory manner. In attempting to find another metal or alloy that might replace copper, the factors of cost and heat conductivity are the main things to be considered.

# Corrosion Problems in the Pulp Plant

*Production by Sulphite, Soda and Kraft Processes Introduces*
*Necessity for Application of Special Construction Materials*

THE production of chemical wood pulp is invariably attended by corrosion difficulties. Inasmuch as both acid and alkaline reagents are employed, depending upon the process, the problems involved are extremely varied. In order to present these problems, together with the various materials used in combating them, a questionnaire has been prepared and sent to about 100 mills in the industry. The results of this study, as presented here, therefore represent a broad range of experience.

Sulphite pulp problems are perhaps the most troublesome, because of the necessary production and handling of calcium bisulphite liquors carrying free sulphurous acid. Most of the difficulties in the sulphite mill are traceable directly or indirectly to this source. For those not familiar with this process it may be briefly outlined to include burning of sulphur to form $SO_2$, absorption of this gas with lime-water, digestion of wood chips under pressure with the resulting liquor, recovery of $SO_2$ gases and liquor during cooking or digestion, and finally freeing the pulp from the acid-lignin residue. The apparatus involved includes sulphur burners, headers for distributing the hot gas to coolers, absorption towers for forming the acid, cylindrical upright digestors for cooking, a tank system for gas recovery and acid storage, and "blowpits" into which the pulp is forced from the digestors and where also a large part of the necessary washing is completed. In addition, the refining of the pulp requires rotary screens of one type or another (knotters and deckers) and a screen and riffle system for removing heavy foreign material and oversize fibers.

The corrosion that begins at the sulphur burners is generally mild, although it occasionally becomes serious. Pan type burners are still used, although rotaries, such as the Glens Falls, are more generally favored. When the former are employed, an acid brick lining in the sheet-iron pan is usually built in. In the latter a steel drum with cast-iron heads is used—the heads standing up for 12 years or longer, the drum being somewhat less durable. In modern practice the combustion chamber that follows the burner is of steel with brick lining and baffles.

From the combustion chamber the gases pass through headers to coolers. One concern reports only mild corrosion at the headers, but the consensus indicates that a real difficulty exists here. In older plants glazed sewer tile was used for the header, but cast iron is now more common, standing up from 1 to 5 years. Ordinary cast iron is most commonly used and if $SO_3$ formation is held down, if the temperature is held up as high as possible consistent with maximum $SO_2$ formation and if the sulphur burned is low in moisture, operation is not a serious problem due to corrosion. It may be mentioned in passing that outside corrosion of the header is sometimes serious. A low concentration of $SO_3$ in the acid plant is very common and when moisture is present, the action is decidedly corrosive. In the same way all metal in the vicinity of sulphite plants is subject to the action of moist $SO_2$, and for this reason the liberal use of protective coating is imperative. A base coat of red lead with a cover coat of asphalt paint is often used for this purpose.

In cooling the hot gases to the temperature most favorable for absorption, various types of apparatus are used. The upright pipe system over which water is sprayed or the submerged pipe (pond type) is most commonly favored. Provision for removing any sulphuric acid formed by condensation from $SO_3$ in the gas should be made through taps or otherwise. Because of this acid condensation cast iron cannot be used; soft lead stands the acid action satisfactorily, but its shortcomings from the structural viewpoint are against it, copper and bronze have been found to fail due to straight corrosion. Apparently hard (or chemical) lead is more favored than any other material for this purpose. The point of most serious attack ($H_2SO_4$ mist) in pond type coolers is near the water level just above the level of the ashes that collect here.

Usually suction is maintained on the coolers, pressure on the towers. Corrosion of the fans used runs from mild to serious. They vary in material—bronze, antimony lead, aluminum, cast iron, lead-covered cast iron have all been tried and most of these materials are used to some extent. One engineer of long experience finds that in the impeller type of fan cast iron gives as long a life as bronze. Aluminum, it is generally agreed, is an unsatisfactory material, while a bronze impeller in a lead housing has been found to give very general satisfaction—the impeller usually lasting upward of 12 months. A cast-lead fan with bronze runners and a Monel shaft is highly favored by some.

Two types of towers are commonly used for forming the acid bisulphite liquor. In the Barker tower system the reaction is carried on between a solution of slaked lime and the gas; in the Jennsen tower the reaction is between limestone, as such, and the gas, water being run over the stone to form the liquor. Both types of tower are constructed of reinforced concrete, usually lined with dense vitrified acid-proof brick with joints of
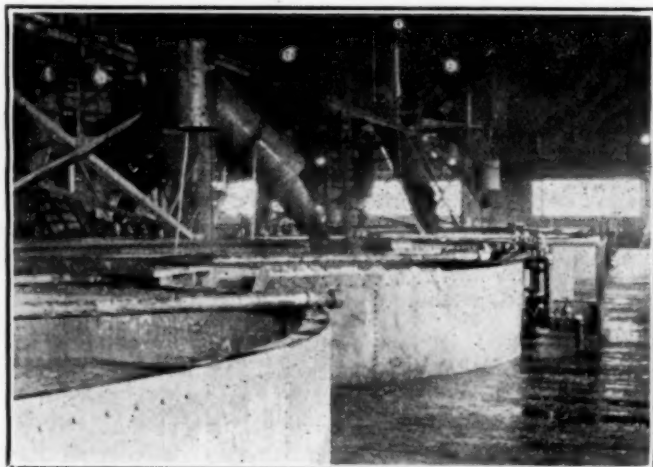


Washing Pans Used in Soda Mills

glycerine-litharge cement (sometimes sodium silicate is also added). These joints require repointing every 18 to 24 months in order to maintain the lining in good condition. Aside from this lining the only other material used in the Jennsen tower is a wooden framework on which the limestone rests. In the Barker system, where a plate tower is used, copper is customarily employed for the perforated floors and for the door liners, although hard lead has been found a more satisfactory material. Wooden towers are still used for absorption in some plants. Although corrosion is nil, the operation of such towers involves difficulties that render their use increasingly uncommon.

Piping and pumping the acid liquor demands the use of material that can withstand the action of sulphurous acid carrying sometimes a small amount of free SO$_2$.
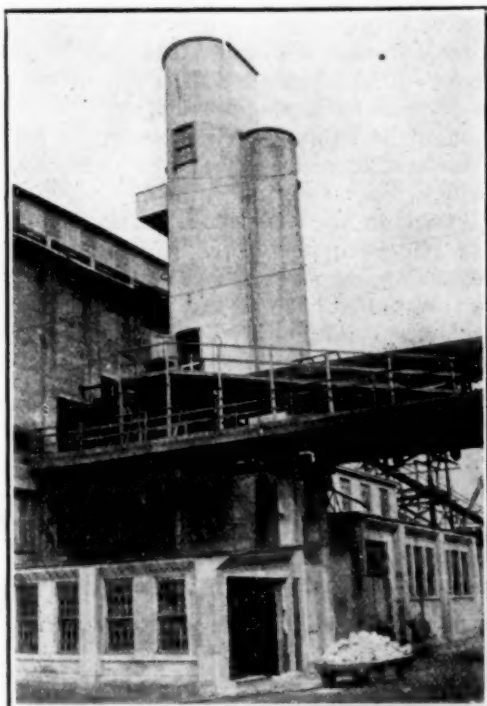


Jennsen Acid Tower System

For low-pressure pumps and limes, hard lead (6 per cent Sb) is common. Another material used successfully by one concern is fiber piping saturated with asphalt or sulphite waste liquor. For high pressure, bronze (as 90 per cent Cu, 10 per cent Sn) or lead-lined cast iron is used. The latter has been found by one concern to corrode rather readily at the joints. Drawn aluminum pipe has been tried without satisfaction. Monel lining for pump lining is found to withstand the acid action very well. Where lead lines are used, valves are commonly of bronze. Due to its tendency to crawl, lead pipe is not favored especially, but its first cost, as compared with bronze, seems to be the controlling factor in its wider use. Bronze, however, finds many uses where no other materials have been found equally good, as in the fittings and valves of the digester. Here the grain of the metal must be fine, free from segregations and slag spots. Occasionally bronze is coated with asphalt to lower its porosity.

Corrosion in the digester proper is met by the use of various special lining materials. The body of the apparatus is usually of riveted boiler plate. Acid-resistant brick (dense, unglazed) are used commonly for protecting this plate from acid action. Difficulties are introduced by the scouring action of the chips, by spalling of the bricks due to the wide temperature range and by the necessity of keeping the pointing of the joints in good condition. A cement of litharge, quartz and glycerine serves the purpose of this pointing reasonably well. Properly constructed of a good grade of brick, the life of such a lining runs from 7 to 10 years.

From the digester hot acid gases are allowed to escape during the period of cooking. These are sometimes cooled in hard lead tubes submerged in water. Because of the pressure of these gases (up to 40 lb. per sq.in.) and the temperature (up to 150 deg. C.), construction must be strong as well as acid resistant and for this reason bronze or copper is increasingly preferred. Aluminum pipe has also been used for this purpose. From these coolers the gases pass to the acid storage and recovery system, consisting of wooden tanks (yellow pine very often) in older plants or of concrete tanks lined with digester brick in modern practice. Corrosion by the hot acid gases is serious. Brass, copper, bronze and lead are used, the latter being found desirable where temperatures are high. Van Stone joints with the brass, copper and bronze give better satisfaction than thread joints, which have been found in several cases to be eaten out rapidly. Renewal of this piping is found to be necessarily frequent even when every care is taken in construction.

When the chips have been sufficiently digested with the acid, they are forced by the pressure of the cooking system through a cast-iron or bronze blow-off pipe into the blowpit. This is constructed entirely of wood, of wood with drain tile bottom, of wood-lined concrete or entirely of tile. Concrete, untreated, will not stand under the action of the acid; tile is very satisfactory except for its first cost; wood with drain tile bottom is a construction finding considerable favor. Of the woods used, long leaf or yellow pine is common and cypress is also used. In the construction of pits from wood the use of copper nails and bronze bolts is found essential.

In some plants all liquor from the digester blowpits is run through a saveall system for the recovery of all possible fiber. Inclined screens of aluminum have given good service in this use, lasting a year or longer. It is highly important that such screens do not touch other metal whereby a galvanic couple might be set up.

The final refining of the pulp is conducted in screens of various sorts—diaphragm, rotary and centrifugal. Although corrosion is not serious in ordinary practice, it is recognized to be a cause of gradual deterioration. Nichrome has been tried for the rotary screens or "deckers" with excellent results, although brass, bronze and occasionally copper are more common. (The latter is probably most common on the rotary type, while bronze takes first place in the plate type.)

### Alkaline Processes for Pulp Production

Many mills remove lignin from wood by digestion with a caustic liquor containing either caustic soda and soda ash or caustic soda and sodium hydrosulphide. The former is known as the "soda," the latter as the "kraft" process. From the point of view of corrosion the troubles incident to both processes are essentially the same. A brief outline of procedure will clarify the steps involved. Chips are cooked with alkaline liquor, sodium salts are removed from the pulp in the form of "black liquor." This black liquor is evaporated and subsequently burned in a rotary calciner. The ash

formed is leached or in case of the kraft process is dissolved and the necessary conversion of carbonate to hydroxide is effected by causticization with lime.

Unlike the sulphite process, the alkaline processes introduce no acid corrosion problems and for the major part the solutions to be handled do not give rise to serious difficulties. Digesters need not be specially lined, since ordinary boiler plate steel gives long life in service under the conditions employed in cooking. Seamless welded construction is generally preferred to riveted. Circulation of the hot liquor in the digester is frequently maintained by means of steel, cast-iron or Monel metal pumps. In handling black liquor and caustic liquor around the plant, ordinary pumps with cast-iron impellers are satisfactory. A packing of asbestos and graphite has been found to withstand service conditions as well as any material, although this problem has not been very satisfactorily solved.

Reports on corrosion of the washing pans, rotary filters or diffusers, where the black cooking liquor is removed from the pulp, vary from "none" to "very appreciable, especially at pulp level line." Steel and wrought iron are usually employed in construction of the pans, diffusers and the bodies of filters. Monel metal wire screen is used on the facing of the latter. Screens and deckers are not found subject to appreciable difficulty, brass and bronze being very satisfactory construction materials. Storage of liquor is likewise usually in mild steel tanks, and corrosion occurs principally on the outside.

Evaporation of the black liquor is carried on in various types of apparatus, but charcoal iron tubes are generally favored for this service over steel tubes. When disk evaporators continue the dehydration, steel is the usual material of construction. In the smelters used in burning down sulphate black liquor, special brick of close-grained soapstone, magnesite or chrome are found necessary.

Leaching tanks and causticizing tanks for dissolving out the soluble salts from the ash and converting the liquor with lime are constructed of concrete or steel, the latter being generally favored. Where towers are used for causticizing, cast-iron sections are used and where the lime mud is filtered, cast-iron rotaries with Monel metal facing stand up satisfactorily.

Bleaching is usually in tile-lined cement or in wooden tanks. The latter are also used frequently for storage of pulp. Hard pine and cypress are the woods favored, the former being less expensive, but otherwise less satisfactory than cypress. Concrete, often lined with tile, is favored by some for storage.

Although the pulp-producing industries are not commonly thought of as being beset by corrosion problems, it is evident that many difficulties do exist. This summary, based on the experience of many technologists who are leaders in the industry, is intended not as a complete symposium but rather as a step toward clarifying the situation. To all those who have contributed ideas and materials, opportunity is taken here to express appreciative acknowledgment.

---

# Food Products Fight Contamination

### Acids in Fruit and Vegetable Products Present the Most Perplexing Problems in This Industry, as Metallic Salts Are Highly Objectionable Impurities

IN THE food products industry, contamination of product—a factor that is recognized in several other industries, particularly dyes and fine chemicals—assumes commanding proportions and must be considered at almost every point in processing and packaging edible materials. Although the acids encountered in food products might be considered relatively weak from the chemical viewpoint, they nevertheless are sufficiently corrosive to cause a great deal of trouble. In the distribution of these products, the time factor is frequently much more important than is the case with chemical products, and the problem of finding containers that will satisfactorily resist the corrosive action over a long period of time is a most serious one.

#### FRUIT AND VEGETABLE PRODUCTS

Practically all fruits and many vegetables have an acid reaction. In some cases the acid is developed during the processing, as is the case with vinegar and sauerkraut. This acidity is closely related to the flavor and appearance of the product and it has not been found possible to alter the acidity without impairing the quality. Accordingly, equipment for preparing such products must be able to resist corrosion and in addition the containers for distributing the product must be able to withstand the action over a considerable period of time. In the remarkable development of the canning industry, this point is one that has caused a great deal of trouble and has been the subject of extended careful investigations by such organizations as the research laboratories of the National Canners Association at Washington and of the Dominion Canners, Ltd., in Ontario. While it is impossible in a limited space to give detailed consideration to the problems of individual products, it may be worth while to summarize the results of these investigators.

#### CANNING PROBLEMS

From the canners' point of view, vegetables and fruits may be divided into three groups, according to their acidity expressed as hydrogen-ion concentration. Corn, peas, beans and asparagus are only slightly acid, corn being nearly neutral with a $p_H$ of 6.3. In a middle group come tomatoes having a $p_H$ of 4.5. Raspberries, strawberries, blueberries, cherries, pears and apples are decidedly acid and form the third group. The $p_H$ values for this group range from 3.9 to 2.9. Members of the first group produce slight corrosion, although it has been pointed out that certain protein or amino bodies will dissolve tin. With such a product as tomatoes, the interior of the can will usually have a galvanized appearance, but corrosion seldom proceeds to a dangerous point. With this middle group, pinholing does not occur.
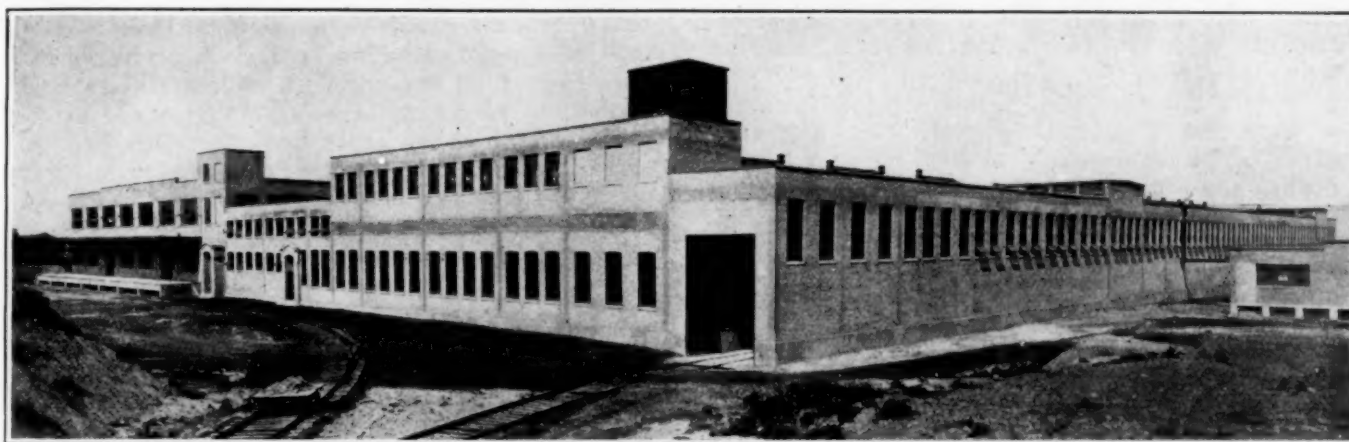
Typical Modern Food Products Plant—United States Gelatine Co., Carrollville, Wis.

Corrosion attains its maximum with highly acid fruits and perforation frequently takes place. This is the group that causes the canners trouble and losses are often severe.

With all these products, corrosion is very greatly accelerated by the presence of oxygen. It follows, therefore, that it is important that the can be tightly sealed. In certain porous products, such as apples, pears and strawberries, a large amount of air is present in the fruit itself, so that it is very difficult to prevent this accelerating effect of oxygen, even though the cans are sealed in a vacuum. In addition, it is now believed that fruit contains some substance of oxidizing potential other than free oxygen. This is probably a substance containing oxygen in combination which it gives up with sufficient ease to accelerate corrosion. If a can of apples is left open for a few days on the table with free access of air, the can will soon become severely corroded. It has been found in the case of apples that the free oxygen as well as the unknown substances of oxidizing potential are removed by the enzyme naturally present when the apples are soaked in dilute brine after peeling. This may prove to be a solution of this particular problem, although the effect of the treatment on the flavor of the product will have to be studied carefully under commercial conditions.

Products such as strawberries, raspberries, cherries, beets, etc., possessing a red color, present an unusual problem. When packed in plain tin cans, the hydrogen produced by corrosion or something in the corrosive action itself destroys the coloring matter by reduction. In order to prevent this, it has been found necessary to coat the tin plate with a lacquer or enamel. One of the great problems of the canning industry is overcoming perforation in certain fruits packed in enameled cans. Products that do not perforate plain cans do sometimes perforate these enameled cans to such an extent as to cause large losses.

The question of perforation has also been attacked from the angle of the manufacture of the tin plate and also of the steel base itself.

It will be seen from this brief outline that corrosion is a serious problem in the canning industry. Some of the problems that still await satisfactory solution may be summarized as follows:

It would be of value in the study of this question to understand more intimately the mechanism of corrosion and the conditions that influence it. A more intimate knowledge of the substances of oxygen potential would be of value. It has been found that steel made by the same process and substantially identical as far as can be determined by chemical and physical examinations differs greatly in resistance to perforation with acid fruit. Further information is desired regarding the desiderata of steel employed in making packers' cans. No method is known for plating steel with a tin coating of uniform thickness. Any improvement that can be made in the uniformity of the thickness will contribute to the overcoming of corrosion.

## FRUIT PRODUCTS

In processing many other fruit products such as juices, sirups, jellies, jams, etc., the action of the fruit acids makes necessary the use of corrosion-resistant equipment.

Crushers for extracting juice may be of iron in the case of grapes and apples, but for berries and citrus fruits must be of bronze, aluminum, silver-plated or nickel-plated metal or other insoluble material. Pulp filters for juices are usually copper or brass plated with tin or silver. Filter presses may be wood or plated metal.

For heating juices or boiling jellies, open kettles are used. As the time of heating should not be unnecessarily prolonged, small units are preferable and the question of heat transfer is important. Enamel-lined kettles are best for citrus fruits and the rate of heating may be increased by using silver-plated steam coils. Steam-jacketed kettles of aluminum or copper (plain, tin-plated or silver-plated) are also quite common. Vacuum evaporators of copper, enamel-lined steel or aluminum are used in concentrating fruit sirups.

## VINEGAR

In the manufacture of cider vinegar, corrosion starts from the time of pressing juice from the apples, and the corrosion problem does not end until the vinegar is shipped out in wooden barrels. The difficulties have been overcome to a certain extent by using wood wherever possible. For handling the liquors, manufacturers depend upon the use of rubber hose, wooden log lines and brass pipe. Iron pipe is not suitable, for the reason that it is badly attacked by the vinegar and results in discoloration of the product. In a few plants, hard rubber pipe is used, but this is not general. On most tanks and lines, brass valves are used, as these are not badly attacked and are most satisfactory from the cost standpoint.

In some special machines and equipment in use in the manufacture of vinegar, Monel metal parts are used.

These have given very satisfactory service, although they are subject to slow attack and some plants have shown preference for hard rubber.

There is a decided need in this industry for a metal or alloy that is insoluble in dilute acetic acid (below 7 per cent concentration), suitable for pipe lines and fittings and procurable at a lower cost than brass.

### VEGETABLE OIL REFINING

In vegetable oil refining there is one point at which corrosion occurs to a considerable extent. This is in the tanks in which the soap stock or foots are decomposed with sulphuric acid into fatty acids. Wood tanks with brass pipe, valves and fittings stand up well under the concentration used. The brass pipe, valves and fittings are gradually destroyed, but the general opinion seems to be that they are more economical than the more expensive acid-proof pipe and fittings, such as Duriron, etc. It is possible that the relatively high first cost of Duriron has had much to do with the formation of this opinion. One argument offered in favor of the use of brass for this purpose is that replacements can be obtained at a moment's notice and repairs easily made by any pipe fitter. The tanks themselves stand up very well, wooden tanks that have been in service for 10 years still being in good condition.

### MEAT PACKING INDUSTRY

There are a number of factors that make corrosion a serious problem in the meat packing industry.

Refrigeration equipment is a big item, and in the use of salt brine and calcium chloride brine there are bound to be leaks in the system and some salt carried in the vapors. In connection with refrigeration by means of salt brine showered through sprays and trickling over exposed direct expansion ammonia piping, there is rapid corrosion of the exterior of the piping. In the cold storage rooms there is also more or less condensation on the walls, ceilings and piping, as well as on metal doors and other metal fittings.

There is a great amount of steam and vapor from the various cooking processes and there are numerous acids and ammonia fumes in the air at various points in the plant. In hot and steamy departments, such as rendering and fertilizer drying sections, there is special tendency to corrosion of exposed structural metals. The vapors from the inedible rendering tanks are particularly corrosive and attempts to protect the exposed metal parts from the action of these vapors by means of paint have not been entirely satisfactory. At one plant, all paints submitted are tried out over a door that comes out of the inedible rendering room. So far, the paints have all failed within a few days or a few weeks at most. One of the best materials has been found to be red lead and oil, although this will not stand up in the location referred to for more than 3 or 4 months. Recently a cement paint made by the Tenemec Paint & Oil Co., Kansas City, Mo., has been tried with very encouraging results on iron and steel work throughout the plant, and also on sprinkler pipe. The inside of the steam rendering tanks or digesters is also especially subject to corrosion.

### GELATINE

Gelatine solutions will pick up heavy metal, such as copper and zinc, particularly in the evaporators and reciprocating pumps. For edible gelatine, where the permissible limit of these metals is very low, this is most objectionable. Aluminum evaporators, enamellined pipe, centrifugal pumps with special impellers and Monel metal parts have all been used in combating this action. The industry is still in search of standard valves and fittings that are sanitary and made of material sufficiently strong to withstand the usual rough treatment given valves and fittings and sudden temperature changes as well. Aluminum fittings fall short in this respect.

### CARBONATED BEVERAGES

Solutions of carbon dioxide, particularly those prepared under pressure for use in soda fountains or by bottlers of carbonated beverages, are decidedly corrosive. The carbonators in which these solutions are prepared are carefully lined with block tin, and the carbonated water is distributed through pipes that are also lined with block tin. Soda fountain fittings that come in contact with fruit acids are heavily silverplated over block tin.

---

# Corrosion Dragon in the Sugar Industry

*Even Harmless Non-Corrosive Materials Like Sugar Present Difficult Corrosion Problems Differing in Type From the Specific Corrosive Action in Some Processes*

THE corrosion problems encountered in the refining of cane sugar and in the production of beet sugar are of a different type from those connected with the manufacture of other chemical engineering products. It is less a case of the corrosion of an individual piece of equipment by specific reagents than of general corrosion. In cane sugar refining there are four distinct types of corrosion that are encountered. The first of these is the corrosion due to strong sugar solutions. The second is that due to the so-called sweetwaters, the filter press wash waters, and to the waste waters from bone char washing. Third is the acid corrosion of equipment due to phosphoric acid and sometimes to hydrochloric acid when the phosphoric acid is made at the sugar house. Finally, there is the corrosion due to water, which in a sugar house is a considerable factor, since the quantity of water used is very large.

The rules for combating these various types of corrosion are simple, though complete success is far from attainment. With strong liquors there is no corrosion if they are pure. In such cases wrought-iron pipe can be used with complete satisfaction. Impure concentrated liquors, however, contain substances that accelerate corrosion to a marked degree, and invariably such liquors are handled in copper. There is a tendency to use copper throughout inasmuch as it permits a more flexible handling of the liquors.

Copper must be used on the sweetwaters, as the corrosion of iron is extremely rapid. The waste waters
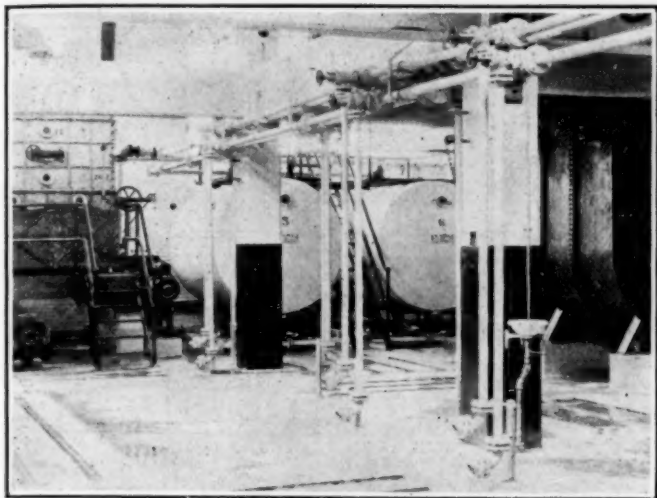
**Aluminum Evaporator, Enamel Lined Tanks and Pipe in Edible Gelatine Plant**

from the bone char filters present an even more difficult problem, inasmuch neither copper nor iron will withstand the action of the ammoniacal materials that are always present. Cast iron seems to be the most satisfactory solution to this difficulty.

### PHOSPHORIC ACID CORROSION

Hydrochloric acid corrosion has been discussed elsewhere in this issue in a special section devoted to this material. There are, however, some interesting points connected with the use of phosphoric acid in sugar house work. Lead pipe has been successfully used for circulating-phosphoric acid for intermittent service. Yet it was found that if continuous circulation were employed, the presence in the acid of oxygen and of the lead phosphate coating dislodged from the inside of the pipe causes both corrosive and abrasive wear, which makes lead unfit for this service. Lead valves showed even greater deterioration under these conditions. Duriron stood up well under the corrosion, but before the reinforced Duriron cock was brought out the material was too brittle for hard service. It was formerly customary to use wood tanks with cast-iron outlet

pipes and earthenware cocks reinforced with stay rods. Now it is customary to line the tanks with antimony lead.

The corrosion of pipes with water of various kinds is serious. On the seaboard, refineries use a great deal of salt water as condensing water. Experience seems to indicate that cast iron and government bronze are the two best metals for this service. Pump rods of Monel metal have been used with great success both in reciprocating and in centrifugal pumps. There is a good chance that stainless steels may prove advantageous also.

A peculiar phenomenon has been widely noted where aërated water is supplied to a district. For example, since the New York City supply has been taken from the Catskill reservoirs, where it is strenuously aërated, the corrosion of factory pipes on water service has been much more rapid than formerly, when non-aërated water was used. Steel is good, but it corrodes. Monel metal is also good and does not corrode, but the price is stiff. Of the other metals bronze is also good, but somewhat brittle.

There are special cases of corrosion that are not so serious. Evaporators and vacuum pans do not corrode rapidly unless the frequent use of acid is necessary to dislodge the scale. This will depend on operating methods and conditions. Acid washings are sometimes necessary, but ought be used as a last resort.

### Some Beet Sugar Problems

The process of extraction of sugar from beets and its subsequent refining presents still more peculiar problems. First, the work is seasonal, the campaign lasting only about 100 to 125 days. This means that for 8 or 9 months of the year the equipment stands idle. It can be readily understood that this long intermission would present a corrosion problem of first magnitude. It is, of course, universal practice to clean thoroughly all equipment after the close of the campaign. It is then painted or oiled. Coal-tar or graphite paints, such as those made the Detroit Graphite Co., are satisfactory, though some superintendents prefer oil and one, at least, whitewash.
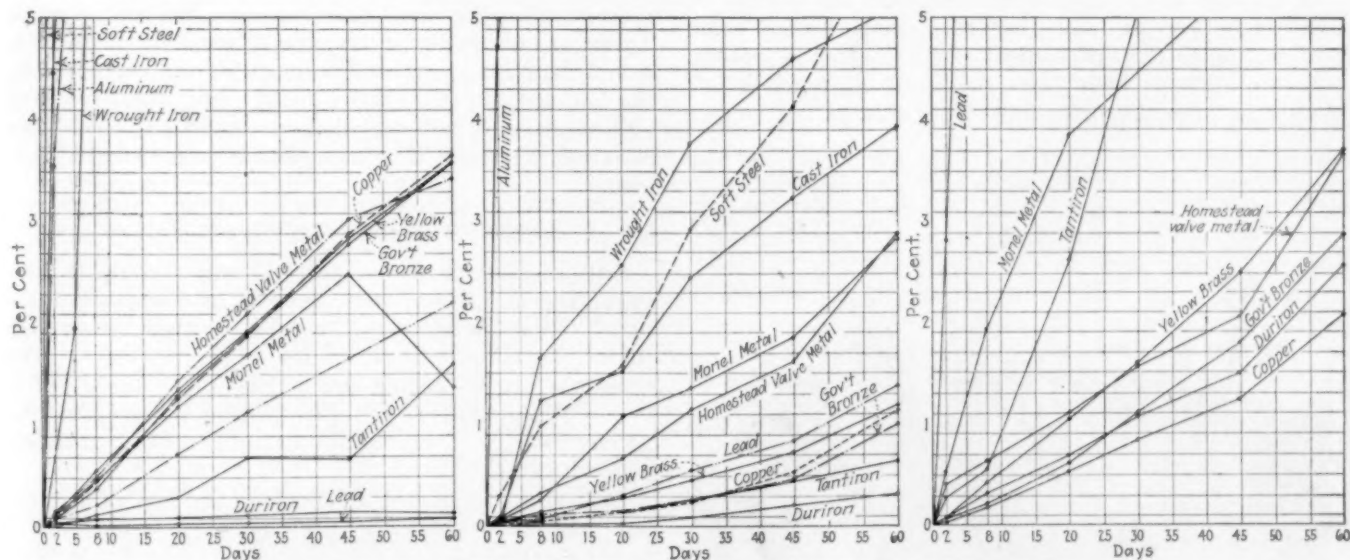


**Resistance of Metals to Corrosive Solutions Used in the Sugar Industry**

Left—Solution of Bowkerosa paste diluted to 18 deg. Bx. Paste contains 60 per cent $P_2O_5$, 5 per cent CaO and is diluted roughly 1:3. Center—Filtered solution "blackpaste" 58 deg. Bx. Essentially monocalcium phosphate (13 per cent $P_2O_5$) with trace of free HCl. Left—Commercial 16 deg. Bé. (24.5 per cent) hydrochloric acid.

We are indebted to Dr. J. W. Schlegel, of the National Sugar Refining Co., for the data from which these curves are plotted. In each case the time in days is plotted

against the percentage loss in weight of a sample of the metal immersed in frequently renewed and agitated quantities of the solution at room temperature. The curves give an approximately quantitative idea of the resistance of the metals.

The accompanying diagram tells the story of the beet sugar process. Beets are received in railroad cars and are dumped to storage, from which they are drawn as needed to be topped, cleaned and sliced. The slices are slender pieces called cossettes, from which the sugar may be extracted easily. This is done in a diffusion battery, a series of large tanks filled consecutively with fresh beets. Extraction is effected by water which flows through six to eight tanks, gradually becoming stronger and stronger until it reaches the concentration of the beet cells. The first tank in the series is, of course, the most nearly exhausted and as soon as the sugar content is at a minimum the tank is cut out and emptied. Tank No. 2 then becomes the first tank and another tank of fresh beets is added to the end of the train. The extracted beet pulp is pressed, dried to about 12 per cent water content and sold as cattle feed.

The liquors are now purified. This is carried out in much the same way in all plants, variations being of detail and not of principle. Sometimes liquors are strained before they are defecated and at other times milk of lime is added and then carbon dioxide (the defecation process) without preliminary clarification. Acidity of the solutions is most carefully controlled throughout this part of the process. The calcium carbonate precipitate is settled and filtered and the filtrate is defecated a second time. This time sulphur dioxide is added as a bleaching agent to the carbon dioxide. The filtered liquor may sometimes be further purified, but is usually run to evaporators for concentrating, then to vacuum pans and centrifugals. The sludge cake from the filter presses is found to be valuable as fertilizer and is so utilized.

To return to corrosion phases of the process, the following materials of construction are used for some of the severely treated equipment of the factory:

1. Raw juice piping, standard wrought-iron pipe.
2. Diffusion tanks, steel sides and steel perforated screen.
3. Raw juice pumps, cast iron.
4. Sulphur stations, cast iron and copper for pipe steel for tanks.
5. Evaporators, cast iron and steel.
6. Concrete floors.

A number of interesting minor points are worthy of mention either as indicating a valuable use of some material or an unusual method of eliminating corrosion. Sulphur stations have been the cause of much grief. Although some factories have been able to use copper



Corn Products Refinery, Edgemere, N. J.
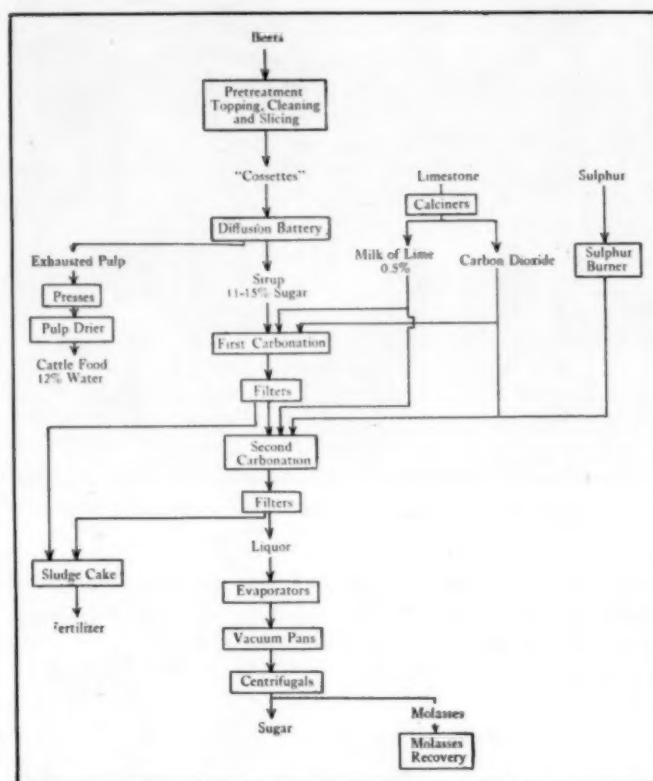


Flow Sheet of Beet Sugar Process

and steel, others use only cast iron, with a notable diminution in the ravages of corrosion. It is fairly safe to say that modern practice has proved the value of cast-iron pipe throughout this part of the process. Again, the vent pipes from these tanks are ruinously corroded if they are metal, and the tendency is now to keep them painted and pray for long life. It is a question whether concrete or tile ducts would not solve the problem.

Carbon dioxide pumps corrode somewhat, but this may be largely prevented by using plenty of oil.

The presses and driers used on the beet pulp deteriorate more rapidly than would be expected. At present cleaning and painting are the only cures. Again, the air ducts for the pulp driers that range from 4 to 5 ft. in diameter suffer greatly from corrosion by the hot wet gases. In one factory the usual cleaning and painting is not regarded as important, since they replaced the ducts with some made from Armco ingot iron.

### Corrosion With Ammoniacal Vapors

Still another corrosion problem was serious in beet sugar plants. It was the corrosion of evaporators and tubes from ammoniacal vapors evolved from the juice. This has been overcome in several ways. The ammonia can be vented out or the juice can be boiled in the air previous to concentration in the evaporators. In any case cast iron has been found to be of considerable advantage.

Beet sugar corrosion is considerably less of a problem than it would be if the campaign lasted for 12 months. Obviously, if you multiplied corrosion by four many things that seem rather minor would become major problems. But that is not the case, and hence the general corrosion during the shut-down will probably continue as the largest problem.
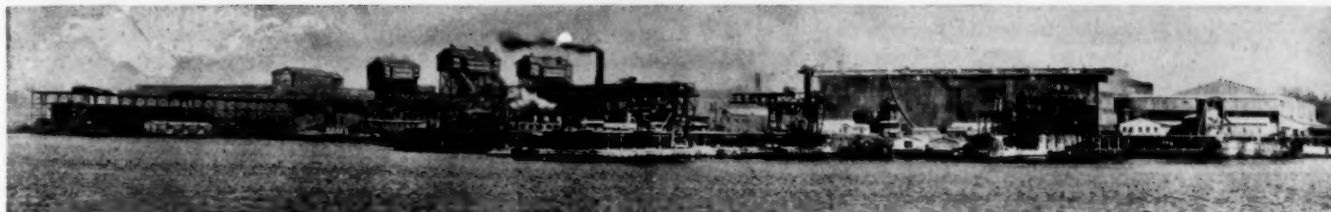
Plant of the Davison Chemical Co., Curtis Bay, Md.

# Corrosion—The Constant Menace of the Chemical Industry

### No Plants in the Chemical Engineering Field Are Subject to More Varied Corrosive Action Than Those Producing Heavy Chemicals

THE "Gourmand of Industry" is in his favorite stamping ground in the heavy chemical industry. Ever on the alert to destroy, to cut down production efficiency, to brand apparatus "worn out" today that was new yesterday, the toll that he exacts is appalling. It seems strange, in the face of such a situation, that so few successful attempts have been made to control this ruthless destroyer. Old methods of production remain in use because no material is known that may be fabricated into apparatus to displace the clumsy equipment that has come to be thought of in the industry as standard.

If satisfactory workable materials were to become suddenly available, materials that would stand such acid action as that of hydrochloric at boiling, the heavy chemical industry might progress more in a year than it has since 1860. In the same measure, acid-consuming industries would profit.

Such an advance must eventually come. The awakening of engineers to the dollars-and-cents significance of this industrial menace has been compassed during the past 2 years. Concerted effort alone can win through to a solution of this problem.

To that end engineers and manufacturers must pool their experience. The topics treated in this section represent a step in the direction of co-operation. It would be impossible fully to survey the field, for some manufacturers still cling to the idea that their experience is unique and priceless, that they will give more than they get in any exchange. But this present survey of the most important chemical products has been made possible through the generous co-operation of a number of the most progressive manufacturers in the chemical industry. It has been our privilege to act as the medium of this work.

In explanation of our selection of materials for treatment it should be said that we have confined ourselves to those processes that presented major corrosion problems and to those materials that had widest use in consuming industries.

---

## Sulphuric Acid

### Its Manufacture by the Chamber and Contact Processes Introduces Problems Common to Many Consuming Industries

THE manufacture and use of sulphuric acid involves many corrosion problems—considering the extent to which this acid is used perhaps more difficulties may be traced to this single source than to any other. An idea of the basic position of this industry among the acid industries is indicated by the table on the following pages. It is to be borne in mind that even these many uses represent but a fraction of the total for which sulphuric acid is employed.

Since most of the difficulties occurring in the industrial utilization of this acid occur at one step or another in its manufacture, an outline of the problems encountered in production either by the chamber process or by the contact processes may throw light upon the present status of available means for reducing corrosion losses. In manufacture $SO_2$ and $SO_3$, both moist and dry, must be handled over a wide temperature range. Acid of all concentrations, also over many temperatures, must be moved and stored. In general the fans, pumps, tanks and pans are the sources of most constant difficulty.

A brief outline of the chamber process will serve to indicate the points at which many of these troubles arise. Either sulphur or pyrites is burned to give a gas carrying 5 to 11 per cent of $SO_2$, a small percentage, usually under 0.5 of $SO_3$, 7 to 14 per cent of $O_2$, some water vapor and the remainder nitrogen. Dust is removed from these hot gases in special collecting chambers. They then pass into a Glover tower, where they come in contact with a down-flowing stream of weak sulphuric acid. When niter pots are used for the necessary addition of nitrogen oxides, they are usually placed between the dust-collecting chambers and the Glover tower. From the top of this tower the gases are usually drawn by a fan and forced into the first of the chambers under slight pressure. Passing from the chambers, the gases flow up through a Gay-Lussac tower, where the nitrous acid gas is scrubbed out by means of strong sulphuric acid. If a concentrated acid is desired—over 60 to 65 per cent $H_2SO_4$—some sort of concentrating equipment is essential, usually the tower type or the cascade type.

Comparatively little corrosion trouble is experienced in the burning of the pyrites or sulphur, the latter

raw material being at present more commonly used. Various forms of burners are employed, of which the Glens Falls rotary typifies practice for materials of construction when sulphur is burned. Cast-iron heads with a steel drum come in contact with the molten sulphur and with the hot gases, carrying, as has been stated, 5 to 11 per cent of $SO_2$ at 1,100 to 1,200 deg. F. In pyrites burners the usual construction is of steel with firebrick lining. In the flues or headers that carry the hot gases into the dust-settling chambers little difficulty is experienced with cast iron providing always that the temperature is above that of condensation for any water vapor present.

### MATERIALS FOR DRY FANS

When these gases are forced under pressure into the Glover tower, fans with steel blades in a steel casing are found satisfactory by some manufacturers, although it is not agreed that this material is thoroughly suitable for this use. Cast-iron fans have given good service where, as is also necessary with steel, the casings have been carefully kept tight. It is practice in some plants to douse the blades with soda ash solution whenever the casings are removed and in this way a life of several years has been obtained. Special bronze has also been used on hot fans without bad effects in at least one large plant.

Dust-settling chambers may be constructed of brick and cast iron or steel. These metals can be used, since here again the gases are hot and dry. From this point on, however, the problem becomes more serious, since the evaporation of the weak acid in the Glover tower adds moisture to the exit gases. Nitrogen oxides are often present here. The combination is highly corrosive, demanding an unusually resistant material for the cold fans. Antimony lead, carrying about 8 per cent Sb, is used with as much satisfaction as any material concerning which information is now available, although Duriron fans have been used for this service.

The chambers are built of the purest soft lead obtainable. In plants where the niter is added in the form

of a spray in the first chamber, antimony lead nozzles are commonly used. These are sometimes tipped with platinum and used for the addition of water to the chambers as mist as in the Schutte & Koerting apparatus. Unless carefully regulated, addition of niter in the form of nitrate solution involves a serious corrosion problem, in that the building up of nitric acid concentration on the chamber floors to a point where they are readily attacked is possible. Properly operated, however, this system probably introduces no more corrosion troubles than do the niter pots in common practice. When pots are used the nitric acid vapor is usually generated in an enlarged part of the main flue leading to the Glover, heat being supplied by the gases. Slop-over pans must be provided for the material that boils over and also some means has to be arranged for the tapping off of the acid sulphate formed by the reaction of the sulphuric acid and nitrate. In some plants regular cast-iron nitric acid retorts are used for generating these nitrogen oxides.

### MOVING AND HANDLING ACID

Acid handling is a serious problem at the chambers, as it is at the towers where several times the tonnage of acid produced must be circulated for purposes of cooling, evaporation or recovery of nitrogen oxides. One large company uses Lewis pumps on all acid up to and including chamber strength. These pumps are constructed of lead and Duriron, of the vertical packingless type. Duriron pumps are also found quite satisfactory on chamber acid. When 48 to 50 deg. Bé. acid must be pumped, soft lead, despite its drawbacks from the point of view of construction, is the only serviceable material. Either straight air lifts or acid eggs are very frequently preferred to centrifugals for moving the more troublesome concentrations of acid, of which this is one. A combination of stoneware and "bario metal" is used in one pump of the open-impeller, side-suction type for handling acid with results that may further its application.

The exit gases from the chambers pass into the Gay-Lussac tower, usually built of heavy lead with chemical stoneware packing. Coke and pumice are also used occasionally for this purpose. The construction both of this tower and of the Glover is entirely of non-metals with the exception of the side walls and the distributors for the acid at the top. These are usually built of antimony lead. Some towers are now constructed entirely of acid-proof masonry. In such cases a cement "Duro" containing 96 per cent silica and 4 per cent sodium silicate is commonly employed. It has been found that fluorine in the gases exerts a very destructive effect upon the towers—a peculiar form of corrosion that can only be avoided by eliminating this material at the source; that is, by introducing no materials carrying fluorides.

Storage of cold acid up to 30 per cent may be in either wood or lead. Lead-lined wooden tanks are often used here because of the dehydrating effect of the acid on the wood, an effect which of course causes leaks very readily. Special bronzes such as Everdur are found satisfactory for acids of very low concentration—probably more so than any other known material. From 30 to 80 per cent the acid may be handled in soft lead, even at boiling temperatures, with satisfaction. When soft lead cannot be used because of its tendency to crawl, the hard leads are available, some sacrifice of corrosion resistance being necessary in order to obtain

#### Relation of Sulphuric Acid to Other Acid Industries*

*A—Direct action of sulphuric acid (usually upon a natural salt or byproduct of another process), liberating free acid.*

| Acid Set Free | Natural Salt or Byproduct Source |
|---|---|
| Acetic | Acetates, wood distillation industry |
| Boric | Borax from lake brines |
| Carbolic | Coal-tar fraction, after caustic extraction |
| Carbonic | Limestone or marble |
| Chlorsulphonic | Chlorine and sulphuric acid |
| Citric | Citrates, citrus fruit industry |
| Gallic | Tannic acid, extracts industry[1] |
| Hydrobromic | } Brines from mines and lakes |
| Hydrochloric | |
| Hydrocyanic | } Gas; coke and beet sugar industries |
| Hydroferrocyanic | |
| Hydrofluoric | Fluorspar or cryolite |
| Hydrofluosilicic | Fluorspar and sand, or byproduct phosphate manufacture, fertilizer industry |
| Mixed | Mixture, nitric and sulphuric |
| Nitric | Chilean saltpeter |
| Phosphoric | Bone ash or phosphate rock |
| Phthalic | Naphthalene, coal-tar industry, with catalyst[1] |
| Tartaric | Tartrates, wine industry |
| Valerianic | Fusel oil, distillation industry, with bichromate[1] |
| Vanadic | Carnotite ores, byproduct radium industry |

[1] Action of concentrated sulphuric acid—oxidation.

*B—Action of sulphuric acid, after a preliminary operation.*

| | |
|---|---|
| Chromic | Alkaline fusion chrome iron ore, then sulphuric acid |
| Silicic | Alkaline fusion quartz, then sulphuric acid |
| Tungstic | Alkaline fusion tungsten ore, then sulphuric acid |
| Formic | Alkali heated under pressure with CO or $CO_2$. |
| Hypophosphorus | Barium hydroxide heated with phosphorus |
| Lactic | Specific bacterial fermentation, starch paste or sugar from corn, potato, molasses, etc., neutralised lime, then sulphuric acid |
| Oleic | Alkaline saponification, fats and oils of slaughtering and meat packing, olive and cottonseed oil industries, then sulphuric |
| Stearic | Similar to oleic |
| Oxalic | Formic acid process continued with more heat, neutralised lime and sulphuric acid added |

* From Census of Manufactures Report

the desirable strength. Cast iron bridges the gap for acids between 85 and 98 per cent at boiling and lower. Acid between 80 and 85 per cent presents one of the most serious problems faced by the chemical engineer handling sulphuric acid. Usually either lead or cast iron is resorted to, but the life of either is short. Ferrosilicon alloys resist the action of the acid somewhat better than straight cast iron, but constructional difficulties do not indicate that such alloys, in their present state of development, are the final answer to the problem.

### AN IMPROVED LEAD LINING

A construction that should be mentioned here is the "Zeitler"—a so-called homogeneous lead lining for a metal tank. This apparently gives much promise, especially in the process industries where sulphuric must be heated. At present lead coils in a lead-lined tank are used, with much crawling and many blow-outs, even if the steam pressure is below the supposed safe pressure. The construction in question is being placed on the market by the Oakland Copper & Brass Works and consists of a crimped wire screen, tinned, that is riveted with copper to a tinned steel plate. Lead may then be cast onto this screen to any desired thickness with satisfactory retention. The tin alloys with both steel and lead, thus insuring optimum heat transfer.

For cold fuming sulphuric acid, steel is as serviceable a material as any for all-round use, although at elevated temperatures no material is known that will stand up under this action for any length of time. Sixty degrees Centigrade is near the dividing line of temperature. Steel pumps, operating at this temperature on 103 to 109 per cent sulphuric, give a life of a year, but slight temperature increase reduces this life to weeks. When this temperature must be exceeded, earthenware lifts or eggs must be used along with apparatus of like material for storage and handling.

Whenever strong sulphuric is stored, it is necessary to keep air away from it, because of its avidity for moisture. Thus steel storage tanks that are entirely satisfactory for 98 per cent acid are rapidly attacked if the concentration falls. The same consideration applies to the handling of "empties" that have transported strong sulphuric. It is essential that such cars on their return to the plant should be sealed in such manner that no air can react with the small amount of strong acid clinging to the sides of the tank.

### CONTACT SULPHURIC ACID

Up to the dust chambers, the contact process plant is equipped in the same manner as the chamber plant. Following passage through these chambers, however, more careful purification of the gases is essential than is necessary where a readily poisonable catalyst is not employed. Briefly, the apparatus consists of scrubbing towers of one sort or another, of drying towers for removing any acid mist introduced in the scrubbing, of heaters for elevating the temperature of the gases that are cooled during processing, of means for maintaining circulation both of the gases and of the acid, of a contact tower where $SO_2$ is converted to $SO_3$ and of a series of absorption towers where the trioxide is absorbed by dilute sulphuric acid. Variations in the apparatus mentioned here will occur in the different modifications that exist of the contact process, but as far as corrosion is concerned the operation here will typify the difficulties that exist.

Cast-iron grids may be used in the scrubber tank and a cast-iron pump for circulation of the hot acid that may be stored in a steel boiler plate tank. This acid usually runs from 93 to 98 per cent in strength. Mild steel towers are used for taking the acid spray from the gases, and in the towers that are used for the final elimination of this spray coke is placed on cast-iron supports.

Cast-iron pipes at red heat are used for bringing the gases up in temperature before passing on to cast-iron towers in which the gases come in contact with the platinum catalyzer. From this point on corrosion becomes serious. Cast iron is used for pipes and steel for coolers, but these materials are attacked much more readily by the trioxide than by the dioxide that was handled up to this tower. The trioxide apparently forms sulphate in the pores of the cast iron and this in time tends to disrupt the line with explosive violence. Wrought iron has been used in place of cast iron, the balance here being as usual between life and cost.

In the absorption towers, acid brick linings set with Duro cement are found to resist the action of the acid fairly well.

Where interchangers are used in the contact plant, a serious problem is sometimes encountered in keeping the tubes in good condition. The exit gases at a temperature of about 200 deg. C. will throw down acid at 100 to 150 deg. if they carry any moisture. A life of 3 months or less for the tubes results. Welded joints in this apparatus are especially susceptible, having been found to stand up less than 15 days if the moisture content of the gases is appreciable.

### CONCENTRATING SULPHURIC ACID

When chamber acid must be concentrated to 98 per cent acid, as is quite frequently the case, a very difficult problem must be solved. Usually either cascade or tower evaporation is used. Conditions that must be maintained are extremely bad for apparatus, whatever its material and construction. Add to the normal concentration of sulphuric the presence of a small amount of nitric acid, as is the case where spent acid from the dye or explosives plant is to be recovered, and the problem becomes one of the "nastiest imaginable," to quote an engineer who has had long experience in this work.

In this recovery of spent acid, steam is passed up a tower down through which the acid is passing. Such a tower is usually built with a steel shell, lined with acid-proof cement and packed with quartz tile. Under these conditions most of the nitric is volatilized, to be condensed in apparatus similar to that outlined in the section devoted to that acid. The sulphuric, which may run around 70 per cent carrying small amounts of nitric, is generally taken down in a pan cascade evaporator. This apparatus is also used for ordinary concentration of chamber acid.

A series of pans are set, one slightly above the succeeding one, over a long flue of acid-proof masonry set with an acid cement. These pans, with the exception of the ones directly over the fire, may be of lead. Duriron or Vitreosil may be used for the entire system, the former being common in the final or "strong" pans. Where iron pans are used the mud thrown down cakes on the bottom and causes "burning" of the pans.

Fumes, with acid mist, are carried away through an overhead hood that may be built of Duriron slabs with sand over the joints. The exhausting of these fumes

requires platinum apparatus if nitric is present—no other material stands up under this combined action.

In the tower system of concentration, construction may be much as in the usual Glover or Gay-Lussac. Hot flue gases are run counter-current to the dilute acid, which is circulated by means of a pump until the required concentration is obtained. When this system is employed, as in other systems of concentration, exit gases are likely to carry a considerable percentage of acid mist. Formerly coke-filled lead towers were used alone for scrubbing or "filtering" this out, but at present electrical mist precipitators of the Cottrell type are also used in several large-scale installations. Such apparatus is invariably of the pipe type, bottom and top headers being of lead, with collecting electrode either of lead or of tile. If coke-filled scrubbers are not used in connection with these precipitators, the use of a lead cooling coil for the gases is quite essential, as the mist cannot be efficiently removed above a temperature of 200 to 210 deg. F.

## Hydrochloric Acid

*The List of Usable Materials Is Here Reduced to Lowest Terms, So Great Is the Corrosive Activity of This Substance*

WHEN the chemical engineer tackles hydrochloric acid, whether for its manufacture or use, he comes closer to hearing the jaws of the corrosion dragon snap than at any other time. Whether present in vapor or liquid phase and whether pure or impure, the substance has few equals for the viciousness with which it attacks materials of construction.

By far the largest quantity of hydrochloric acid is made from salt and sulphuric acid, though by a peculiar twist in economics some is now made from excess chlorine by burning with hydrogen. The first process from a chemical standpoint is extremely simple and from an operating standpoint most unpleasant. Salt and sulphuric acid are mixed in an inclosed, heated cast-iron pan, the products being sodium acid sulphate, sodium chloride (one-half the original amount) and hydrochloric acid, which is evolved. After a period that varies from 1 to 3 hours the residual mass is pushed into a muffle roaster, where it is spread out in a thin layor and turned over with rakes or long-handled shovels frequently (every 15 minutes) until no more hydrochloric acid is evolved. The salt cake ($Na_2SO_4$) is then raked out into caves or loaded directly into cars. Two types of calciners are used, the reverberatory and the muffle, the latter being more usual, as it produces better acid. The evolved gases are condensed and absorbed in water.

This is a meager outline, but will serve to locate the corrosion problems of the process. The first of these is the pan. It is hardly fair to attribute pan mortality to corrosion, for the temperature changes are extremely severe. The material cakes on the pan unless great care is exercised, and ultimately the pan will crack. It is, of course, an academic question as to the relative importance of corrosion in this deterioration process. The facts are that pans last from 3 days to 8 or 9 months. Random and somewhat inconclusive experiments have been made on the kind of cast iron most suitable for this severe service. The problem must still be regarded as unsolved.

No other metal is encountered until the cast-iron

headers are reached for bringing the gases to a common stoneware main preliminary to condensation and absorption. This metal can be used here, as the gases are extremely hot and not as corrosive as most gases. The other material used in vapor hoods, arches and muffles is acid-proof brick.

As the gases cool off to their condensing point the list of "possible" materials for handling them diminishes. Stoneware, hard rubber, fused silica, glass and bitumin are most commonly employed. The condensing equipment, including tourills, receivers, scrubbing towers, etc., is usually stoneware. Fused silica has recently loomed up as a rival largely by reason of an improved design of condensing unit than because of any particular advantage that the material itself possesses.

### How to Pipe and Pump Hydrochloric

Other difficult problems in the manufacture and use of hydrochloric acid revolve around the pumping, piping, storing and shipping of the material. Metal pumps and pipe are unsatisfactory, although where air can be excluded some metals give fairly good service, copper, for example, and several bronze-like alloys, of which Everdur is an example. Where pumps and pipes are in continuous operation such an alloy can be used. Hard rubber pumps give good service except where the packing comes into contact with the acid. Stoneware blow cases and air lifts are more widely used than pumps for moving hydrochloric and if properly installed are satisfactory. Hard rubber and glass are superseding stoneware for riser lines and piping, although here the motto has always been: Where possible don't have lines for hydrochloric acid.

Then at the end of the maze of tourills, absorption bottles, scrubbing towers, etc., there is usually a suction fan which can be made of lead inasmuch as the concentration of hydrochloric acid is extremely low.

Shipping hydrochloric acid is a problem of considerable interest at the present time. Glass carboys are the standard, but many significant experiments are under way in the use of rubber-lined tank cars. Some companies have in the past used heavily packed wooden tank cars with smaller tanks placed across the car frame. Both hard and soft rubber linings for steel tanks have proved satisfactory and bid fair to become invaluable commercially. A typical example of this type of construction is Olivite. A clean metal base is coated with a suitable binder such as rubber cement. Then a special rubber mix is spread on and is subsequently vulcanized on the surface. In this way a hard rubber surface is in perfect contact through a resilient cushion with the metal casing. It can be used not only for tanks cars but for pumps, vessels, blow cases and possibly even for pipe.

No product better illustrates the need of constructive work on new materials than hydrochloric acid.

## Nitric Acid

*A Vigorous Reagent So Widely Used That the Experience of the Producer in Cutting Corrosion Will Benefit a Legion of Consumers*

WHEN the chemical engineer speaks of nitric acid manufacture he invariably visualizes the decomposition of niter (sodium nitrate) with sulphuric acid. The other processes have hardly yet attained commercial significance and hardly possess the background of

corrosion-resistance experience that would warrant their receiving attention.

The process consists essentially of heating equal weights of niter and 66 deg. Bé. sulphuric acid in a cast-iron retort. Nitric acid is evolved along with other oxides of nitrogen and is condensed and absorbed. A great many different systems of operation and of condensation and absorption are used. They differ both in principle and in detail. All plants, however, begin with a cast-iron retort heated with coal or oil or gas. The retorts are sometimes made of soft cast iron, but high-silicon iron is becoming more usual practice. The retorts last from five runs to 500 runs. The corrosion is most serious at points of imperfection in castings, such as slag spots. When retorts are not completely surrounded by brickwork, the upper part where the acid condenses toward the end of a run is more seriously corroded.

The leader pipes that carry the hot nitric acid gases from the retort to the condensers are usually made of high-silicon iron, though terra cotta is sometimes used in spite of its tendency to crack under the heat. Fused silica and quartz are also used, but are fairly expensive for this service, as the mortality in resetting is high.

### CONDENSING NITRIC ACID

Condensers are built with two ideas in mind, to recover all the nitric acid vapors and to produce as colorless acid as possible. In other words, the nitrogen peroxide is fractionated out and recovered later as nitric acid. From a material standpoint the design matters little. Many installations of nitric acid condensation and absorption still exist in which the stoneware coils and stoneware Wolff bottle are used as the units. More modern plants tend to use either the Hart condenser, which consists of two silicon iron manifolds joined by a huge number of Pyrex glass tubes over which water trickles, or the so-called S-bend condenser with nothing but horizontal connections. The latter is made in Duriron (high-silicon iron) or fused silicon. Receivers of stoneware or Duriron complete the condensing system. One interesting point in connection with the Hart condenser is the putty, used to lute the glass tubes to the manifold. It is made of asbestos and oil and remains soft for a long time, thus insuring the necessary elasticity for uneven expansion.

The next step in the process is the absorption system. Stoneware bottles have been mentioned, but they are obsolescent. Towers are almost invariably used now. These should be of stoneware or glazed terra cotta, faced with acid-proof material and set in saucers of granite or stoneware. Duriron has not proved satisfactory here, as the impurities in the acid are sufficient to form dilute aqua regia.

For moving nitric acid vapors various systems are in use. There are, first, pans of Duriron or stoneware. A company that has made extensive studies of this problem of handling nitric acid vapors and other nitrogen oxides uses Duriron nozzles for steam jet. They recognize that it is wasteful of power, but are satisfied to make this sacrifice in order to avoid fan troubles. On Volentmer systems that employ a vacuum of 21 in. for operating, a reciprocating pump was originally used, but modern plants are using liquid seal rotary pumps for the purpose and to much better advantage.

Pumping nitric acid is not done often, although on some concentrations the Duriron pump is satisfactory. More often blow cases and air lifts are used. Lead

lines are used sometimes, but glass lines are much more common, either of Pyrex or ordinary glass, using flanged and clamped joints. There is one plant that has a 3-in. line of Pyrex glass half a mile long for concentrating nitric acid.

Aluminum is frequently used on dilute nitric acid and should be satisfactory up to 80 per cent. However, impurities in either the nitric acid or the aluminum causes disintegration. An interesting example of the effect of impurities is the corrosion of aluminum shipping containers. They deteriorate first at the corners where the nitric oxide is known to accumulate, it having been shown that nitric oxide diffuses away from flat surfaces.

## Electrolytic Alkali and Bleach

### Chlorine and Caustic Soda Formed in Process Require Unusual Care in Handling if Equipment Is to 'Be Maintained

THE manufacture of electrolytic bleach is interesting in that the process includes production of caustic soda or soda ash and chlorine-materials that are known to be highly corrosive. These products result from electrolysis of salt solution. Chlorine, by reacting with lime, forms the bleach solution desired.

Equipment of carefully selected materials is essential for brine preparation, for electrolysis, for absorption of the chlorine in lime water, for evaporation of the caustic, for the handling and storage of these various materials during the process.

Depending upon the type of cell used, the brine must be purified with varying degrees of care. In the Allen-Moore cell, for instance, a very pure brine carrying a small percentage of free acid is essential for successful operation. This necessitates special processing equipment for the salt solution. In general the same considerations will apply here as in the section devoted to calcium and magnesium chloride brines.

Wooden tanks of long-leaf yellow pine are found most satisfactory for solution (with hot water) and for treatment with soda ash, barium chloride and hydrochloric acid, although concrete is used quite extensively for this construction. Previous to the addition of the acid the brine must be filtered to remove the sludge. Steel bodies may be used for such filters, but bronze is the material found most durable. Corrosion here is rather serious, especially on the leaves if the Kelly type is used or on the frames if the Shriver is employed.

For piping brine solutions cast iron and wrought iron may be used, but with less success than bronze. Valves such as the Sphero, manufactured by Fairbanks and made of brass, are used in several plants for this service, although cast-iron valves of the rising gate type are preferred by some engineers of long experience, despite the fact that their resistance to corrosion is only fair.

The material found most suitable for cell construction varies widely with the type employed. For the Allen-Moore the main body is of concrete with a protective coating of natural asphalt paint. In this cell the iron cathode plates tend to corrode rather rapidly, although it is found desirable to use this material despite this effect. In the Hargreaves-Bird, concrete has been used as a body material with less resistance to corrosion than cast iron with an earthenware lining. In the Townsend cell a cast-iron body with a

concrete lining is found most satisfactory. Although other cells are extensively used, the above practice indicates general practice as far as materials of construction is concerned.

From the cells, chlorine may be conducted in mains of terra cotta to the absorption system. When this gas is dry, it does not attack iron seriously and as a result in large plants the effort is to dry the gas and use iron mains. Such drying may be conducted in towers packed with pumice in which strong sulphuric acid is circulated. Terra cotta is not attacked, but it is open to the old criticism of being fragile and full of joints that must be carefully luted if vacuum is to be maintained on the system. Hard rubber lines have also been used in handling chlorine, as also have fiber pipes coated with asphalt. For maintaining suction, Nash Hytors of cast bronze running with sulphuric acid, located on the vacuum side of the absorption towers, are found very satisfactory, although several other forms of exhausting equipment can be used, since the chlorine concentration here is low.

The absorption towers are usually built either of concrete or of tile with packing of chemical stoneware. Usually these are operated in series, in which case corrosion is more serious in the first tower, where the chlorine first enters, than in succeeding towers.

The bleach liquor that results, being strongly oxidizing in nature, tends to attack lead, especially where joints have been burned. Settling tanks are almost invariably of concrete. If the bleach is maintained slightly alkaline, iron pipes are satisfactory for handling. Galvanized barrels are sometimes used successfully for storing small quantities of the liquor. Pulp bleachers are usually of cement with tile lining, although wood is also used and is not attacked rapidly.

The caustic effluent from the cells may be readily
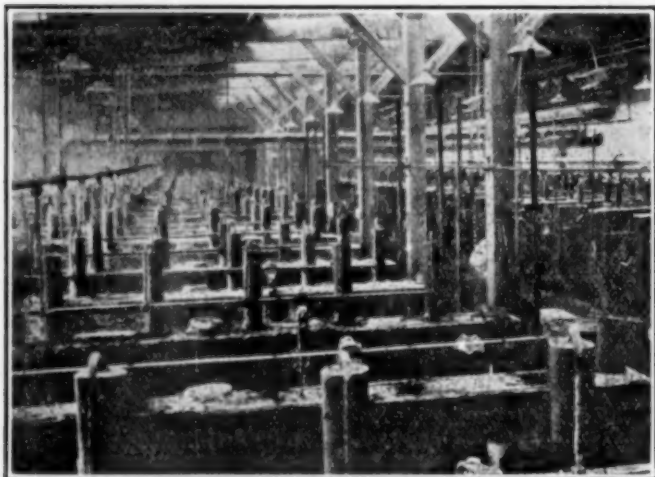


A Typical Allen-Moore Cell Installation

handled in steel tanks. Some embrittling of the rivets is usually to be noted and due to the tendency of caustic solutions to seepage the joints must either be ground or sandblasted. For drains and sumps concrete is used with pumps of cast iron. In this connection reference may be made to the section on alkaline processes of pulp production.

Evaporation of the caustic brine (usually the brine is not fully decomposed and carries as high as 50 per cent of salt) does not present an especially serious corrosion problem, since the ordinary materials of evaporator construction, with only slight modifications,

are found to give good service. Tubes of charcoal iron are almost invariably used and represent the most serious item of necessary replacement. Salt catches are now built very generally of Monel metal, although cast iron and bronze are used occasionally.

In handling caustic soda, brass valves and fittings are not found as satisfactory as the all iron variety. Fusion kettles for carrying the liquid caustic down to the solid form are of cast iron with cast-iron covers. Sheet-iron containers are also usually employed for handling the finished caustic.

Where caustic soda is to be used in process work, as in fusions, nickel is known to be more resistant
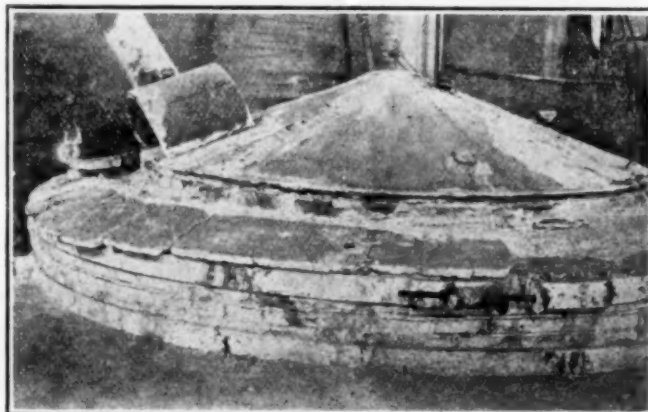


Cast-Iron Caustic Evaporating Pot

than any other ordinary metal, but because of its relatively high expense it is not so commonly used as iron or steel. Where reactions are conducted in which the concentration of the caustic is below 37 to 40 deg. Bé., nickel steel or low-silicon iron are satisfactory. Copper is fairly resistant, but is likely to introduce impurities. Low concentrations of the caustic are difficult to handle mainly on account of atmospheric corrosion, which is greatly facilitated in their presence.

Wood is not a desirable material of construction where caustic solutions must be handled, because it is attacked by all concentrations. On the other hand, after caustic fusions it is sometimes necessary to neutralize with acid without introduction of any metallic impurity. In this case there is practically nothing else that can be used. Lead linings are sometimes resorted to and are not rapidly attacked if the caustic concentration and temperature are low. In filtering caustic solutions, Monel metal wire is sometimes used in place of cotton cloth, because it is not readily attacked and hence gives more economical service.

## Dyestuffs and Intermediates

*Modification of Operating Practice So as to Have Practically Neutral Reaction Mixtures Important as a Means of Evading Corrosion*

CORROSION in the dye industry is limited largely to the effect of acids and alkalis used in the reaction mixtures, as most of the intermediates and finished dyes are quite neutral and do not attack even the ordinary metals such as cast iron. Frequently, however, when in mixture with acids or alkalis, they seem to exert a pronounced accelerating effect on the corrosion rate normally encountered with the acid or alkali in question. The deleterious effect, catalytic or otherwise, of small amounts of metallic salts in many of the

reactions is also a factor to be considered. The industry thus presents a series of individual problems and aside from the distribution system for handling the acids and alkalis up to the reaction vessels, few generalizations are possible.

For the following comprehensive survey of the problems of this industry we are indebted to Dr. Ivan Gubelmann, vice-president, in charge of dyestuff manufacture, The Newport Company.

Corrosion is responsible for large repair bills in plants manufacturing dyestuffs and intermediates. Its destruction varies a great deal in different parts of the plant, depending on the nature of the materials used in the processes, but is usually most noticeable where dilute acids are used extensively. By frequent painting with acid-proof paints, the outside of the apparatus and the steel work can be fairly well preserved, but the corrosion on the inside of the apparatus must be carefully reckoned with when materials to be used for the construction are decided upon.

### RESEARCH AND CORROSION

Many research chemists forget that corrosion enters into their problem at a very early stage. They are too often satisfied when they get good results in glass apparatus and consider the development work leading to a successful manufacture on a large scale "just an operating problem." The experienced research chemist does not consider the small-scale laboratory work finished before he has a fairly accurate idea of what materials are going to be used for the construction of the apparatus. Strips or pieces of materials to be used should be immersed in the reaction liquids or masses, weighed before and after, and the corrosion data put on record in the laboratory journal. It is not uncommon to observe that already in the laboratory the method of procedure has to be changed several times as a result of these corrosion tests. Sometimes the corrosion tests with a certain metal are very good; still the presence of this metal may be detrimental to the chemical reaction and make its use prohibitive. The corrosion tests, therefore, serve two purposes:

1. To determine whether the use of a certain material insures a reasonable life of the apparatus.

2. To determine whether the construction material lowers the yield or the quality of the product.

With this information at hand, the process is ready for trial on a semi-commercial scale.

### EXPRESSING CORROSION

It is desirable to establish a laboratory record on corrosion of various materials exposed to a number of chemicals, by expressing the corrosion in figures. A convenient corrosion figure is obtained as follows:

A piece of metal 1 in. wide, 3 in. long and $\frac{1}{8}$ in. thick (for instance) is exposed to a certain reaction liquid. The time, surface of the metal and loss in weight are put on record and expressed in grams per 24 hours per square inch. After dividing the weight in grams of a square inch of metal $\frac{1}{16}$ in. thick by the above figure, the "corrosion index" is obtained. This figure indicates the number of days that are required to dissolve a layer of metal $\frac{1}{16}$ in. thick. In actual practice the metal will of course not corrode to the same extent all over the surface. The corrosion may be more severe in some spots, but will as a rule correspond to the "corrosion index" for the largest part of the surface. This faster corrosion in certain places is very often

due to improper agitation during the mixing of corrosive liquids or to a slight variation in the composition of the material of which the apparatus is built. Impure aluminum, for instance, will corrode fairly rapidly in the presence of acetic acid, whereas pure aluminum shows very good resistance to practically all concentrations of acetic acid. Galvanic action is another cause of uneven corrosion, brought about by the improper combinations of metals used in construction. As a rule, however, the "corrosion index" is a rather reliable figure in deciding on the material for construction.

### CORROSION IN ACTUAL OPERATION OF PLANT

Operating men will agree that the lowest manufacturing costs are possible only if a certain manufacture can be carried out without serious interruptions due to breakdowns. Where plants are operated on a shift basis, it is doubly important to see that each operation can be carried out each day according to schedule. The best results are not obtained if an operator has to rearrange his work frequently on account of breakdowns. This is especially true in the case of complicated processes where the plant foreman has to depend a great deal on the reliability of his men. If the same operations occur every day at about the same time, labor economy also is the best. During the time apparatus is being repaired, the operators cannot always be conveniently put to work in some other part of the plant. In cases where corrosion is very rapid, it may be necessary to provide for spare apparatus in order to assure uninterrupted operation.

Although the use of acids causes by far the largest repair bills, it is also found quite frequently that neutral solutions can be very corrosive. The solutions of sodium salts of nitrosulphonic acids or of hydroxysulphonic acids, although neutral, may corrode iron very rapidly. A neutral copper salt solution will of course also corrode iron or aluminum.

Oftentimes corrosion not only causes large repair bills but it will also cause trouble in the manufacture. Although only a small amount of iron may be dissolved in a liquid, the iron hydroxide precipitated by making the solution alkaline will cause filtration troubles. The finely precipitated iron frequently clogs up press cloths and other filter mediums to such an extent that frequently change of filter medium becomes necessary.

A very small amount of precipitated iron may be the cause of emulsions that are very troublesome if an oily liquid is to be separated from an alkaline liquid. In such a case it may be desirable to discard iron apparatus, although the "corrosive index" may be very good.

For the manufacture of intermediates and dyestuffs cast iron, steel, wood and lead are the most important materials used for the construction of apparatus. These are materials that permit the construction of apparatus of almost any desired size at a reasonable cost. Concrete tanks often give very good service, especially if the heating of the contents may be done by steam jets. Copper apparatus is not used as much in dyestuff plants as it is in pharmaceutical establishments, principally for the reason that pharmaceutical products are very often colored by the use of iron apparatus; in the manufacture of dyestuff intermediates the color of the product is not such an important matter. Nevertheless, copper apparatus could undoubtedly find more extended use in dyestuff plants, especially in the handling of solvents.

In cases of severe corrosion, stoneware equipment is frequently installed. By proper handling it is cheap in maintenance, but is available only in limited capacities.

The use of Duriron is often very advantageous in the handling of acids and acid liquors. The bringing out of the Duriron centrifugal pump has been a decided step forward in the problem of conveying acid liquors.

Aluminum has a good "corrosion index" against organic acids. It shows good resistance to concentrated nitric acid and also to ammonia liquors.

Enameled cast iron apparatus is chiefly used for very corrosive liquids, and in cases where metals are harmful to the product or the reaction. It also has limitations as to size and is rather expensive.

Hard rubber equipment is very convenient for the handling of hydrochloric acid, but should be used only for cold liquids. For special purposes, bronze, silver, Monel metal and other materials are used in the construction of equipment for dyestuff plants.

### Evading Corrosion in Dye Manufacture

Another prominent manufacturer of dyestuffs has tackled the corrosion problem from an unusual but most logical angle. In reducing to practice a formula developed in the research laboratory, it is quite customary to consider the formula itself as more or less fixed and to attempt to find materials for equipment construction that will meet the conditions specified. Having tried this method and found it not altogether satisfactory, the company in question was led to experiment with the alternative—modification of the formula so as to permit the use of ordinary materials of construction. On the face of it, the proceeding seemed somewhat precarious, but it was soon found that reactions hitherto conducted successfully only in acid solutions could, after careful study from this new viewpoint, be made to take place just as well in neutral solutions. This, to use the apt designation made by an official of the company, "evades the corrosion problem."

Application of this same line of thought to problem after problem has been attended with most encouraging results. While, of course, not all problems are susceptible to this treatment, it is surprising the number that have succumbed and the reduction in corrosion that has resulted. The idea certainly merits serious consideration by all who are facing corrosion problems, for there are undoubtedly many other cases where it may be applied with equally satisfactory results.

## Alum

*Sulphate of Alumina Proves Troublesome Unless Handled in Hard Lead — Utility of Other Promising Materials*

THE manufacture and use of alum does not introduce problems essentially different from those occurring in connection with sulphuric acid, inasmuch as aqueous solutions of alum usually carry free sulphuric through hydrolysis. Lead and hard lead are found satisfactory for handling alumina sulphate—difficulties arising from its use are not due so much to corrosion as to constructional drawbacks. Since in manufacture, temperatures employed range from room temperature to boiling, lead is found to creep and crack in a short time. It has been found that the recently developed crawl-proof Hoyt metal (6 to 8 per cent Sb) gives several times longer service than lead or alloys previously employed.

The bronzes in general do not stand up in such solutions, particularly if these solutions contain iron in the ferrous or ferric condition. There are, however, a few bronzes of the hard type of more recent development that give considerably greater service.

Duriron equipment gives reasonably long service, but the action on solutions containing iron again, as in the case of bronze, is in some cases more rapid than one would expect; pitting often occurs in a few months in the case of cocks and piping.

## Handling Salt Solutions

*Brines Containing Alkaline Earth Salts Require Unusual Precautions Both to Protect Apparatus and to Insure Clean Products*

THE corrosive effect of brine solutions, especially those carrying calcium and magnesium chlorides, is well known. To L. A. Pridgeon, of the Diamond Crystal Salt Co., St. Clair, Mich., who has had extensive experience in handling such brines, we are indebted for the following observations in this connection:

"The following theory of the corrosion of brine carrying magnesium chloride and calcium chloride may account for difficulties experienced in practice. When $MgCl_2 6H_2O$ is heated above 106 deg. C., hydrochloric acid escapes and a basic magnesium chloride insoluble in water is left behind.

$$2MgCl_2 + H_2O \rightarrow \begin{matrix} Mg< \begin{matrix} Cl \\ \\ O \\ \\ Cl \end{matrix} >Mg \end{matrix} + 2HCl$$
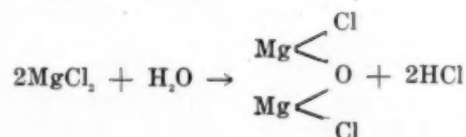
"Heaters that are used raise the temperature of the brine, under pressure, much above 106 deg. C. These heaters are equipped with steel tubes. After drilling the scale off these tubes, the liberated carbon due to corrosion discolors the brine as black as ink. The attack on these steel tubes by the hot brine is many times greater than on steel pipes conveying cold brine.

"A centrifugal pump installed for handling brine at 205 deg. F. was equipped with a steel shaft, cast-iron blades and cast-iron body. After 6 weeks use the shaft was attacked so badly that it was honeycombed for a depth of half an inch. The pump was replaced by one of all bronze and it is still in service and does not show any signs of corrosion.

"On cold brine apparatus there is corrosion which may be due either to electrolysis or to corrosive sulphur gases in the brine. For instance, when an all brass pump with a cast-iron head is used, the head is attacked. When the pump is all brass the steel suction and discharge lines are attacked. Corrosion of steel brine lines has been reduced somewhat by attaching a bond or ground to lead off any stray electrical currents.

"As for pipe lines, wrought-iron pipe stands up better than steel pipe, and cast-iron pipe better than wrought pipe. Many hot brine lines become coated with a layer of gypsum, which tends to protect the metal from corrosion.

"In the salt industry two bad effects come from corrosion of iron apparatus—the deterioration of the apparatus and the discoloration of the salt by the iron oxide. In open pans this last effect has been overcome by building the sides of the pan of Tobin bronze, and rakes and conveyors of bronze or Monel metal.

"General practice in handling brines is to have all pumps bronze or Monel. Steel pipes and steel apparatus are used except for pumps on brine below 180 deg. F. Cast-iron pipes and cast-iron apparatus are found suitable for hot brine. Copper tubes are used for heaters and evaporators. In handling wet salt, brass, bronze or Monel metal is used. Driers are lined with Monel or portland cement mortar. All these precautions are taken, of course, to keep the salt from getting off color by contamination with iron oxide."

# Ammonium Nitrate

### The Explosives Manufacturer Is Forced to Meet Difficult Conditions in the Production of This Essential Compound

THE manufacture of ammonium nitrate involves several corrosion problems in connection with the storage of ammonia and of acid, with the mixing of these constituents with evaporation, crystallization, storage and, last but not least, with the housing for the equipment.

Aqua ammonia (26 per cent) is usually stored in steel tanks. Since moist ammonia gas is known to be more corrosive than the liquid itself, all pipe connections should be made below the liquid level. Copper is known to be on the blacklist whenever ammonia is present. Aluminum and tin, it is said, withstand its action even in the presence of air. For moist vapors, lead piping is recommended unless the presence of rust is not objectionable, in which case iron is satisfactory. Dry ammonia gas or liquid ammonia can always be handled satisfactorily in iron.

From chemical stoneware containers dilute nitric is passed into a weighing jug of the same material. From this container it is run into a brick-lined (acid brick set with acid cement) wooden reaction tub, in which the reaction takes place. This tub is usually underground. A Duriron distributor for the ammonia gas is located in the bottom of this tub. The ammonia is vaporized in a boiler plate steel still, being scrubbed in a tower of circulating $Na_2CO_3$ to remove sulphides before passing into this distributor. A nearly neutral solution of the nitrate results.

This is usually evaporated in round bottom cast-iron pans with steam coils of wrought iron, steel or cast-iron jacketed steel. The presence of ammonium chloride is known to be highly corrosive in this evaporation. Chalk, ferric hydroxide or other anti-acid have been added to prevent building up of free acid concentration through hydrolysis. Insulation of the heating coils from the rest of the machine has also been found to be beneficial in reducing corrosion trouble.

Vacuum apparatus has also been used for evaporation with considerable success, the same general observations regarding materials holding here. The final crystallizing may be either in open cast-iron kettles or in vacuum pans.

Aluminum and wood are favored materials for mixing the finished nitrate, although iron barrels with or without galvanizing are used for storage. Monel metal, bronzes and brasses are attacked by this salt. Tin likewise forms a compound very readily and should not come in contact with the nitrate.

One difficulty attending this manufacture is building maintenance. Cast-iron siding rusts very readily, no protective coating having been discovered to preserve it.

# Acetic Acid

### Usually Regarded as a Weak Acid and Therefore Relatively Non-Corrosive, It Presents Difficult and Surprising Problems in Industry

ALREADY acetic acid has been discussed in connection with two industries. In hardwood distillation and in vinegar production the manufacturer has to cope with it. The laboratory-trained man with a background that began back in qualitative analysis usually regards acetic acid as a weak acid, and therefore unconsciously catalogs it as non-corrosive. He receives a rude shock when he meets this acid in industry. Both liquid and vapor phase are active corrosive agents.

Industrial practice has done much to eliminate the worst of acetic acid corrosion, but ultimate perfection is still a long way off. Many technologists believe that most of the difficulties encountered in commercial production are due to impurities in the acid, such as formic, propionic and butyric acids. This assumption is based on the satisfaction given by such metals as aluminum, for example, with pure acetic.

Commercial acetic is of course made from acetate of lime, one of the products of the hardwood distillation industry, by distilling it with sulphuric acid. Copper or cast iron are used as materials of construction for the stills, which are direct fired. The use of copper presupposes the flushing out of the air in the still and condensers, as the presence of air greatly accelerates the corrosion of copper with acetic acid and will result in a dicsolored product. Copper, aluminum and sometimes silver are used for condensing tubes. The latter gives a life of 6 years, but the temptation to steal silver, because of its intrinsic value, is a distinct drawback to its longevity. Copper is, therefore, more usual for crude acid and aluminum for pure acid. A more recent development indicates the strong probability that admiralty metal with an addition of 2 per cent phospho-tin will find its way into this service. Tests in this country and in England indicate that the material has real promise. No brazing is done, the metal being joined with admiralty metal flanges.

#### PIPING AND STORAGE OF ACETIC

Piping and valves in an acetic acid plant are commonly of Duriron, which stands the corrosive action well and has been limited in a more extended use only by its brittleness, the difficulty of casting and the danger of fracture under stress.

Storage of acetic acid is regarded by operating men as one of the meanest of all technical problems. Hard rubber has proved satisfactory, but the size of a container of this material is still somewhat limited. Soft rubber promises well, but is still an experiment. Wooden tanks that have been thoroughly parafined have proved as satisfactory as anything up to the present time, although an acid-proof brick lining luted with acid-proof cement is preferred by many producers. Metals are not satisfactory for storing acetic acid unless the acid is pure. Glacial acetic acid can be stored in aluminum, nickel, copper and lead in the order of preference. Acetic anhydride, on the other hand, can be stored in steel.

Acetic acid is a real technical problem and illustrates perhaps better than any other chemical that you cannot extrapolate from the laboratory to the plant with satisfactory results.

# How Metals Stand Up Against Corrosion

*General and Specific Data From Many Sources on the Behavior*
*of Pure Metals and Alloys Under the Action of the Many*
*Destructive Agencies Encountered in the Industrial World*

A COMPLETE account of the corrodibility of even a single metal would fill a book of considerable size. A complete collection of such data on the metals used in industry would fill a library, but an account of the behavior of the most widely used metals under industrial conditions can be brought together into comparatively small compass. That is what has been done here. Information regarding some pure metals, gathered by Harold F. Whittaker, of the National Research Council, and data on alloys, collected by Jerome Strauss, of the Naval Gun Factory, at Washington, have been condensed and added to information of a more miscellaneous character from other sources. There is included a report of the symposium on corrosion held during the A.S.T.M. meeting at Atlantic City, at which much that is new in this field was presented.

## Iron and Steel

### Widely Used Where Corrosive Conditions Obtain, on Account of Low Cost and Ready Availability

IN THE manufacture of chemical engineering equipment cast iron is probably more widely used than any other metal. Where cost is weighed against ability to resist corrosion, the adoption of cast iron is frequently the result, not because its resistance to corrosion is high, for in general it is not, but in a surprisingly large number of cases it is high enough considering its cost compared with that of the metals more resistant to corrosion. It can hardly be called a corrosion resistant, even though it is very widely used where corrosion is encountered. In many of these cases it must be frequently replaced, but the cost of this (including labor) is often so low as to make the use of cast iron cheaper or at least apparently cheaper than a more resistant material. Nearly all corrosives attack iron to some extent, but except where contamination of the product must be strictly avoided, this attack is frequently so slow as to be allowable.

Cast iron is used in a great many processes in chemical engineering equipment where it is not even the cheapest material in the long run. Its use has been found possible and it is easy to try the cheapest and most available material first and to continue to use it as long as no serious trouble develops.

A typical composition of cast iron is: Total carbon, 3.0 to 3.75 per cent; phosphorus, 0.5 per cent; sulphur, 0.1 per cent; silicon, 0.8 to 2.75 per cent; some manganese of varying quantity, in addition to solid and gaseous impurities included and dissolved. The addition of alloying elements (notably silicon for acid resistance) provides wide variation of chemical properties, but takes the metal out of the category of "cast iron." The sulphur is the impurity that must be most closely watched if corrosion is a problem. If it goes higher than 0.10 or 0.12 per cent the iron is considered by some authorities to be unsuitable.

In the case of a pure metal or a standard alloy it is possible to make hard and fast statements regarding the corrodibility by various liquids. Cast iron, however, is an alloy made in so many places and by so many methods and often so carelessly that it is impossible to provide such statements with any accuracy. If, however, cast iron is made carefully of known composition, with the knowledge that it will be used for chemical apparatus, it can be depended upon to be perfectly reliable in resisting certain types of corrosion. The maker of such a product can usually be depended upon to know the material that he is producing and to make recommendations regarding its application in specific cases. It is almost impossible to make a statement regarding the average commercial product to which someone cannot take exception, but it is probably safe to say that where resistance to alkalis is necessary, as for instance in their shipment or other handling, cast iron is a pretty safe material.

There are many reasons for the fact that faulty manufacture makes cast iron unsuitable for use under certain conditions. The principal one is lack of homogeneity, a fundamental cause of corrosion, since it provides differences in potential in contact with a solution. This lack of homogeneity may consist in segregations of the allowable constituents of the metal or of slag inclusions or gas inclusions. The lack of uniformity of electrical potential may be due to strains in the metal caused by uneven cooling from the molten state. All of these conditions are frequently encountered in cast iron as well as such corrosion aids as, for instance, the inclusion of particles of sand in the surface of the metal, the sand having become loosened from the interior of the mold. Another surface effect resulting from the method of manufacture of iron castings is a decidedly beneficial one; this is the silicate coating or skin, which affords a considerable protection against corrosion. Where this skin has been machined off or otherwise removed, corrosion greatly increases.

A great advantage of cast iron is the fact that there is practically no limit to the size of castings that can be produced, and there seems to be almost no limit to the intricate shapes that can be made. The ability to produce large vessels of cast iron has an important bearing on corrosion where the principal factor is contamination prevention, for if the vessel is large, the ratio of surface to volume becomes small and contamination is reduced.

#### MILD STEEL

Mild steel as a material of construction in chemical engineering equipment is next to cast iron, if it does not lead it, in breadth of use. As a resistant to corrosion it does not rank high, but its low cost, combined with its great strength and toughness, makes it of extreme importance. The ease with which it can be forged, rolled, welded and machined makes it ideal for strong light parts where corrosion is not a problem or where it is possible to use some means of corrosion

prevention. On account of its availability like cast iron it has been tried for almost every possible purpose and where it can be used the technician has usually a good knowledge of its possibilities and its limitations. Where first cost is of the greatest importance, as is sometimes the case in making shipping containers, and where contamination is not important, steel is, for use with some chemicals, without doubt the best material, but the cases are few where it would not pay to investigate some of the special alloys or methods of surface protection.

# Copper

### *An Important Constituent of Alloys Capable of Resisting Corrosion, but of Limited Value in This Field When Used Alone*

This outline and the five that follow are abstracted from a compilation of information made by Harold F. Whittaker, of the National Research Council.

COPPER is not considered a corrosion-resistant metal, although its resistance to attack in the atmosphere is greater than that of iron or steel, due to a protective coating of oxide formed in moist air at ordinary temperatures. On account of this property and its excellent conductivity, more than one-half of the total production of this metal is used for the manufacture of wire for electrical purposes. About one-third of the total production goes into the manufacture of brass, bronze and other alloys and the remainder is used in sheet form for roof coverings, sheathing for the bottoms of seagoing vessels, and other construction in salt water localities. Water alone does not appreciably affect copper, hence it is quite safe to use copper vessels to boil water for culinary purposes. Some of the acid foods will dissolve the metal, however, which explains the fact that it is not in very general use today for this purpose.

Copper is attacked by most of the mineral and organic acids to a greater or less extent, the rate of attack depending upon the accompanying oxidizing agent. Oxidizing acids such as nitric acid attack copper vigorously, whereas acetic and some of the other organic acids attack it noticeably only in the presence of air. The alkalis do not seriously corrode the metal, although its use in contact with ammonia is most inadvisable. Copper is resistant to oxidation by water vapor at high temperatures, but is susceptible to attack by saline solutions. Even sea water attacks it slowly.

### NOTICEABLE EFFECT OF STRAIN

One pertinent fact that seems to have been proved by experience is that stressed or strained copper is susceptible to local attack. This is particularly true of copper tubes that are used in condensers on seagoing vessels, and experience seems to have shown that proper annealing of such tubes, particularly at bends, is a good investment.

Most of the chemical corrosion products of copper are soluble and there are consequently few cases, if any, in which they provide a protective coating. These products will usually be found as impurities in solution in cases of corrosion by liquids, and as porous coatings in cases of vapor corrosion.

### ACTION OF SPECIFIC REAGENTS

*Acetic Acid.* Many of the stills that are used in the manufacture of acetic acid are made of copper. The stills themselves have given good service, although the first runnings from a distillation are practically always colored with copper salts. This coloration indicates corrosion of the apparatus, particularly of the condenser, before all of the air has been swept out, and for this reason further precautions are usually taken to prevent the surging of air in and out of the condenser. After the distillation is well started the flow from the condenser is colorless, indicating that the corrosion there has ceased.

*Acetic Anhydride.* Corrosion tests given by Calcott and Whetzel show that although this reagent does not appreciably attack copper at 25 deg. C., at 75 deg. C. the corrosion rate increases twenty-fold and is too great to allow of this metal receiving consideration as a structural material in contact with this compound. Other tests are also given which indicate that copper is unsuitable for use in contact with mixtures of acetic acid and anhydride.

*Acids.* Copper is susceptible to corrosion by acids, particularly if oxidizing agents are present. In many cases the air acts as the oxidizing agent.

*Alkalis.* Copper is slowly oxidized in contact with alkaline solutions, according to Thorpe's Dictionary. Calcott and Whetzel report a test in which copper was exposed to a boiling mixture of ten molar parts of KOH and seven of NaOH in a 25-50 deg. Bé. solution. The corrosion was not rapid, but was too great to allow of the metal being recommended for use in contact with this alkali solution. The common objection to the use of copper for handling alkali solutions, according to Whittaker, is that it contaminates the solutions by introducing soluble copper salts that are difficult to remove.

*Ammonium hydroxide* readily attacks copper.

*Aniline* and similar amino hydrocarbons such as the toluidines, xylidines, naphthylamines, etc., have an appreciable corrosive effect upon copper and its alloys, even in dilute concentrations at ordinary temperatures. The reaction is much more vigorous at the boiling points of the reagents.

*Atmosphere.* Moist air readily tarnishes copper and coats it with an oxide that protects it from further attack.

*Carbon dioxide* not only corrodes copper but serves to protect it. Cowper-Coles patented a process in 1908 in which copper was heated at a red heat in an atmosphere of $CO_2$ for a time, after which it was allowed to cool in the same atmosphere. A protective coating of $Cu_2O$ is formed by this operation.

*Carbon monoxide* and other reducing gases coming in contact with heated copper render it weak and friable. Pilling explains this as due to reduction of intercrystalline grains of oxide.

*Chloride solutions* generally attack copper slowly and the use of copper for handling such solutions is usually avoided.

*Citric Acid.* The action of a 5 per cent solution of this acid upon three bronzes each containing more than 94 per cent copper was appreciable, according to tests made by Hatfield. The corrosion loss was two and one-half times as great as that of 14.3 per cent ferrosilicon and in comparison the loss of wrought iron and 0.3 per cent carbon steel was thirty to fifty times as great.

*Dyes and dye solutions* of the thiazine, oxazine and azine series seriously corrode copper apparatus.

*Hydrogen.* Commercial copper is easily damaged by heating in the presence of reducing gases.

*Hydrogen peroxide*, being a strong oxidizing agent, strongly accelerates the corrosion of copper in the presence of acids.

*Iodine.* When this element comes in contact with metallic copper, it readily reacts to form the iodide.

*Lactic Acid.* The same general precautions should be observed in the handling of lactic acid that are used in connection with acetic acid.

*Oils.* Istrati and Teodorescu investigated the solubility of this metal in various fractions of Baku petroleum and found that it dissolved in increasing proportion as the boiling point increased. It was found that the acidity increased in a similar proportion.

*Organic Halides.* With a few exceptions, the organic halides rapidly attack copper in the presence of strong aqueous ammonia, if the halide contains a trihalogen methyl group in the molecule. Doughty claims that the dihalogen compounds attack the metal less vigorously under the above conditions and the monohalogen compounds are without effect.

*Oxygen and Oxidation.* It is apparent that most of the corrosion reactions of copper depend upon an accompanying oxidation reaction, for Rawdon and Lorenz state that in all of the etching methods which they describe an oxidizing agent is necessary. This same idea underlies Eastick's paper. He states that the presence of oxygen accelerates the corrosion reaction.

*Photographic Solutions.* Copper and its alloys are unsuitable for use in handling these solutions because of their fog-producing tendencies, according to the statement of Crabtree and Matthews.

*Salt Solutions.* A recent investigation is described in a Canadian journal. The author claims that copper is generally attacked by chlorides, slightly attacked by sulphates, and not at all by nitrates, and he refers particularly to the salts of potassium, sodium and magnesium. His experiments convince him that in these corrosion reactions the hydrogen-ion concentration had little if any influence.

*Steam.* A statement in Thorpe's Dictionary tells us that copper does not decompose steam even at red heat. Copper is used in many places in contact with steam, particularly for its condensation, and although the copper itself does not decompose steam, it corrodes electrolytically if it has not been annealed to remove the hard and soft spots and local stresses.

*Sulphuric Acid.* This metal is fairly resistant to dilute solutions of sulphuric acid, although it is attacked at higher concentrations and higher temperatures too rapidly to warrant its use for commercial purposes.

*Sulphurous Acid.* Concentrations of sulphurous acid higher than 5 per cent are not often used in the chemical industry. The lower concentrations are usually handled in redwood, since they readily attack most metals and the other varieties of wood. Whittaker makes the statement that lead, bronze and copper are the only metals that are generally employed for work with this acid.

*Waters, Saline.* Copper has been used for parts of ships for more than a hundred years because of its better resistance to sea water than that of iron. Notwithstanding this fact, copper is appreciably attacked by sea water and the greater part of research done on this subject has dealt more or less with the means of preventing or diminishing the corrosion.

# Aluminum

## Corrosion Resistance Due to Some Extent to a Tight Protective Coating of Oxide—Usually Very Slightly or Very Vigorously Attacked

ALUMINUM has been used for chemical construction for comparatively few years. Its costs per pound seems to be high compared with other metals, and this has deterred consideration of aluminum in many instances. If, however, the cost of this metal compared with others is calculated on the basis of unit volume, it compares quite favorably.

When aluminum is exposed to the weather a continuous and adherent film of oxide forms which protects the metal from further contact. This property, in addition to its extreme lightness in weight, gives aluminum a distant advantage over iron and steel.

Aluminum differs from most other metals in its susceptibility to corrosion. It is usually very slightly or very vigorously attacked by corrosive agents. Its oxide coating does not protect it from vigorous attack by hydrochloric acid and alkalis. It does serve as a protection, however, in many instances where the corrosive would rapidly attack a clean aluminum surface. This protection is due to the low solubility coefficient of aluminum oxide in most reagents.

Many instances are known where aluminum has been corroded by materials against the attack of which it is supposed to be resistant. Most experiences of this sort may be explained by the presence of an impurity in the reagent, such as the presence of a chloride in acids, the presence of alkali salts in ammonium hydroxide solutions or contact with mercury salts. Any of these combinations will cause the rapid destruction of aluminum, particularly if the oxide coating should be broken by a scratch while in contact.

One of the best reviews on the chemical properties of aluminum is given in Thorpe's Dictionary, although much additional and more detailed information may be found in the original literature.

### CORROSION OF ALUMINUM BY VARIOUS REAGENTS

*Acetic Acid.* Concentrations up to 1 per cent corrode aluminum with the formation of adherent protective coatings. At ordinary temperatures (20 deg. C.) the lower concentrations of acetic acid do not seriously corrode aluminum, although the corrosion at about 1 per cent concentration is about three times as great as at 5 per cent. As the concentration rises, the corrosion rate gradually diminishes to zero at about 99 per cent. Boiling 1 per cent acetic acid attacks the metal appreciably, the corrosion rate being about four times that of the cold acid. From 1 per cent to 5 per cent the corrosion rate of the boiling acid drops abruptly to about one-half and then diminishes gradually to almost zero at 100 per cent concentration.

The greatest danger in handling acetic acid in aluminum equipment lies not so much in the corrosion by the acetic acid itself as in the effect of impurities that may be present in it.

*Acetic anhydride*, when reasonably pure, does not appreciably corrode aluminum; in fact, this metal is recommended in place of steel for drums to store and transport this material. Mixtures of acetic acid and its anhydride, particularly those containing more than 10 per cent of the former, should not be handled in equipment constructed of aluminum and its alloys.

*Alcohols.* Opinion differs with respect to the corrosion by alcohol. Rüdiger and Karpinski claim that although aluminum is suitable for the construction of mash stills, it should not be used for vats for the storage of spirits, because it is rapidly attacked, thereby causing turbidity and an inferior quality of spirit. Kohn-Abrest describes the attack on aluminum of certain alcoholic solutions in which are dissolved free acids and such coloring substances as tannin, gallate of iron, caramel, etc. The solution is decolorized during corrosion of the aluminum, but when the decolorization has been effected the aluminum begins to oxidize rapidly. Seligman and Williams state that methyl, ethyl, *n*-butyl, amyl and benzyl alcohols attack aluminum at high temperatures if they are sufficiently anhydrous. They maintain, however, that the presence of traces of water inhibits the action.

*Alkalis.* All caustic alkalis attack aluminum very vigorously.

*Ammonium hydroxide* does not corrode aluminum when free from alkali salt impurities. Davis recommends this metal for the construction of ammonia plants. He claims that the maximum corrosion comes with 2 per cent ammonium hydroxide.

*Aniline* vigorously attacks aluminum at temperatures near its boiling point, the aluminum apparently displacing one or both of the hydrogen atoms of the amino group to form an aluminum anilide.

*Boric Acid.* The corrosion rate of this acid is very low.

*Bromine* readily combines with this metal to form the bromide.

*Butyric Acid.* Boiling butyric acid of 99 per cent strength has no action on this metal.

*Calcium Chloride.* Thorpe's Dictionary states in one place that chlorides do not affect aluminum and in another describes the decomposition of chlorides other than those of the alkalis and alkali earths, together with a solution of aluminum and the evolution of hydrogen.

*Calcium sulphate* affects the metal in the same manner as reported under "Calcium Chloride."

*Chlorine* readily attacks the metal forming the chloride. The combination takes place with the evolution of considerable heat.

*Citric Acid.* Hodges states that the metal is not affected by this acid; at most, the attack is only superficial.

*Copper salts*, when present as an impurity in nitric acid, accelerate the attack on aluminum.

*Cresols* may be handled in aluminum equipment if their concentration is not carried beyond about 99 per cent.

*Fatty acids*, such as oleic, palmitic or stearic acids, do not attack aluminum under ordinary conditions. If the acids become anhydrous, they attack the metal vigorously.

*Formaldehyde* does not attack aluminum.

*Formic acid* attacks aluminum very vigorously. There seems to be no analogy between the action of this acid on aluminum and that of the other fatty acids.

*Gelatin* has no effect upon this metal.

*Glycerol* does not corrode the metal, even when anhydrous and at high temperatures.

*Hydrochloric acid* attacks aluminum under almost all conditions.

*Hydrocyanic Acid.* Aluminum is recommended for the construction of delivery drums.

*Hydrogen sulphide* is not corrosive to aluminum.

*Iodine* affects aluminum in much the same manner as the more active halides, although to a lesser extent.

*Lactic Acid.* The action of this acid on the metal is similar in most respects to that of acetic acid.

*Mercury and its salts* are very harmful to aluminum surfaces.

*Mixed acid* that consists of a mixture of sulphuric and nitric acids does attack this metal. There is a disagreement, however, regarding the extent of this attack.

*Naphthols*, when anhydrous, vigorously attack aluminum at high temperatures.

*Naphthylamines* have the same action upon aluminum as aniline.

*Nitric Acid.* The character of the reaction varies with the purity of the aluminum, the impurities present in it, the concentration and purity of the $HNO_3$, the temperature and absence or presence of air. The presence of copper, sodium, magnesium, chlorine and hydrochloric acid as impurities accelerate the attack.

*Nitrobenzene* and similar compounds capable of reduction are stated by Prinz to accelerate the corrosion of aluminum in acids.

*Nitrogen* combines with metal as well as with its carbide to form the nitride.

*Oxalic acid* dissolves aluminum foil in a few weeks at room temperature, but above 57 deg. C. the reaction is more rapid.

*Oxygen.* In a majority of instances where aluminum is attacked by a chemical reagent the initial action is the weakening or the destruction of the oxide coating. The presence of oxygen or oxidizing agents does not as a rule restore the protective coating, but, on the other hand, usually accelerates the corrosion.

*Ozone.* Droste states that aluminum vessels must not be brought in contact with liquids that contain or can form ozone.

*Palmitic acid* attacks the metal vigorously when anhydrous. The action is inhibited by the presence of small amounts of water.

*Phenol* or carbolic acid, unless anhydrous, has no action on aluminum.

*Phosphoric acid* readily attacks aluminum.

*Potassium carbonate*, like the other carbonates, is corrosive when in aqueous solution.

*Potassium Nitrate.* Thorpe's Dictionary states that the fused potassium nitrate has no effect upon aluminum except above red heat, when it is rapidly oxidized to form potassium aluminate.

*Propionic acid* of 99 per cent concentration has no effect upon the metal, although when the concentration approaches 100 per cent the acid attacks the metal in very much the same manner as acetic acid does when it becomes anhydrous.

*Pyrogallol*, contrary to the general rule, does not attack aluminum even when anhydrous.

*Quinol* does not affect the metal even when anhydrous.

*Salt Solutions.* Bailey has stated that aluminum does not corrode in water or in a salt solution from which the air has been expelled. An investigation that was carried out by Crowe indicated that aluminum was generally not attacked by any of the solutions including the chlorides, nitrates and sulphates of the alkali metals and magnesium. It is probable, however, that salt has some effect over a long period of time, as a case described by Foster indicates that aluminum wire becomes embrittled only when exposed to a salt water atmosphere. Smith has also written about the corrosion of this metal by certain solutions.

*Soap,* according to Thorpe's Dictionary, has no effect on the metal.

*Sodium Bicarbonate.* Von Fillinger reports a slight loss in weight when the metal is immersed in a solution of this salt.

*Sodium Carbonate.* Sodium carbonate in aqueous solution is corrosive to aluminum.

*Sodium Chloride.* Apparently this salt is harmless in neutral solutions and dangerous in acid solutions.

*Sodium Sulphate.* When finely divided aluminum is heated to redness with sodium sulphate, the metal is converted to aluminate with explosive violence, according to Thorpe's Dictionary. When this salt is present as an impurity in dilute acetic acid, it accelerates the corrosion.

*Stearic Acid.* This acid does not attack aluminum under ordinary conditions.

*Sulphur,* free or dissolved in carbon bisulphide, does not affect aluminum at ordinary temperatures.

*Sulphur Dioxide.* A statement is found in Thorpe's Dictionary that this gas has no effect upon the metal.

*Sulphuric Acid.* The data given by Hale and Foster show that aluminum is not seriously affected in the cold by very dilute sulphuric acid. Calcott and Whetzel show that with concentrations from 5 to 50 per cent at 25 deg. C. the corrosion rate increases gradually to a maximum of about 0.04 in. penetration per month. The higher concentrations of this acid, particularly at elevated temperatures, are reduced to sulphur dioxide, the aluminum being seriously attacked. Salkowski has tested the effect of sulphuric acid containing hydrogen peroxide and reports that the presence of this oxidizing agent has no effect upon the corrosion rate. Both Seligman and Williams and Whittaker report that a small amount of sulphuric acid in nitric acid accelerates the corrosion of the latter.

# Lead

### Probably the Oldest and Most Widely Applicable Low-Priced Metal Where "Chemical" Corrosion Is to Be Resisted

LEAD may be considered one of the first if not the first of metals used for resisting the corrosive action of acids. Lead was first used for commercial sulphuric acid equipment about 1746, when it was adopted for the construction of sulphuric acid chambers in England. Ever since that date it has been considered the most suitable metal for this purpose. A great deal of the literature is devoted to the resistance of this metal to sulphuric acid, water and saline solutions, owing to its use principally for the manufacture of this acid, for the conveyance of water supplies or for protection against the weather.

Lead is more or less the victim of its environment, owing to the fact that it is "amphoteric," or capable of acting in the role of either a base or acid. It may be expected to act basic if in an acidic environment, and acidic if in a stronger basic environment. Lead oxidizes fairly readily to PbO, which is basic in character, and combines with water to form the hydroxide $Pb(OH)_2$. From the hydroxide, the sulphate and carbonates are readily formed. The above reaction comes into play when dealing with the corrosion of lead by water or dilute salt solutions. The coating of PbO that forms on the surface of metallic lead is not really protective therefore when it is subjected to contact with water. The

sulphate of lead is only very slightly soluble in water and the carbonate of lead is almost insoluble, so that when coatings of these salts form naturally, or are applied to lead surfaces, they usually protect the metal from further corrosion by ordinary water. A rise in temperature usually increases the solubility of lead in water.

Lead in its commercial form is very pure, usually 99.98 per cent or better, and it is surprising to learn that the brittleness of lead which occurs on exposure to certain reagents is attributed to the corrosion of the intercrystalline bond which is thought to contain most of the impurities. The lead crystals themselves seem to be unaffected chemically, but claims have been advanced that in such cases allotropic forms of lead occur.

Smith and Shipley state that a study of the corrosion of this metal "is complicated, not only by its amphoteric character but also by the physical character of the crystalline metal structure, the infinitesimal amounts of intergranular impurities present and the stresses to which lead structures are subjected."

*Acetic Acid.* Lead is quite readily attacked by acetic acid, particularly in the presence of oxygen.

*Alkalis.* Lead is susceptible to corrosion by caustic with the formation of soluble salts, but for the reaction to assume any noticeable proportions the concentration of the caustic must be above 10 to 15 per cent, the temperature must be elevated and usually an oxidizing agent must be present.

*Ammonia.* Pure ammonia gas does not affect lead appreciably even at about 600 deg. C. The surface of the metal becomes somewhat frosted and blistered, but the action seems to stop there.

*Ammonium Hydroxide.* A one-fifth normal solution of ammonium hydroxide scarcely affects lead.

*Calcium Chlorides.* A one-fifth normal solution of this salt has a very appreciable solvent action on lead.

*Carbon Dioxide.* Waters containing small amounts of carbon dioxide protect a lead surface by precipitation of lead carbonate on the surface. If, however, the concentration of carbon dioxide becomes sufficient to form an excess over the amount needed to precipitate lead hydroxide, it tends to increase the solubility of lead carbonate.

*Chlorides.* Chloride solutions are generally considered harmful to lead.

*Hydrochloric Acid.* Hydrochloric acid should never be used in contact with lead.

*Hydrocyanic Acid.* Lead should not be used in contact with pure liquid hydrocyanic acid, principally because it causes decomposition of the acid. Aluminum is usually recommended here.

*Hydrofluoric Acid.* This acid is very corrosive to lead.

*Mixed acids,* which usually consist of a mixture of relatively concentrated sulphuric and nitric acids and which usually contain less than 40 per cent water, have varying effects upon lead, depending upon their composition. Pascal, Garnier and Labourrasse record the fact that pure lead resists mixed acids when they contain less than 30 per cent water. On the other hand, an early article by Veley states that mixed acids have a stronger action on lead than either sulphuric or nitric acid alone. Calcott and Whetzel have given several corrosion tests showing that mixed acids containing 80 per cent water are very corrosive.

*Nitric Acid.* Dilute nitric acid, as is shown by Hale and Foster, is too corrosive to handle in lead at any tem-

perature. Acid of 80 per cent concentration or over in the cold may be handled in lead, in the opinion of one authority, who warns against allowing the temperature to rise in such cases.

*Nitrobenzol.* The rate of corrosion of lead and most of the other metals in acids is quite strongly accelerated by the presence of nitrobenzol.

*Oleum,* or fuming sulphuric acid, which consists of a solution of sulphur trioxide in 100 per cent sulphuric acid, very actively corrodes lead.

*Organic Acids.* The effect of weak organic acids on this metal has been observed by Gaines, who states that in general dilute solutions attack the metal. The effect of fatty acids arising from fruit and cider, sour milk, etc., is noted in Spon's handbook.

*Photographic Solutions.* Crabtree, Hartt and Matthews have carefully investigated the suitability of various metals for contact with photographic solutions. Lead is mentioned among the more resistant metals and is said to be permissible, although there are other metals that have superior qualities both from the standpoint of resistance and their influence upon the solutions.

*Sodium Carbonate.* A one-fifth normal solution of this salt has no action on lead.

*Sodium Chloride.* A one-fifth normal solution of this salt only slightly attacks lead, according to Hale and Foster. In fact, Whittaker approves of using lead for tank linings for solutions of this salt when necessary. An article written in 1886 by Lunge indicates that at ordinary temperatures lead is quite resistant to salt solutions, but he shows that at 100 deg. C. 2 hours contact proved lead to be more readily attacked than copper, wrought iron or cast iron.

*Sodium Hydroxide.* The attack of a one-fifth normal solution is quite appreciable at ordinary temperatures.

*Sulphuric Acid.* Briefly stated, lead is attacked practically not at all by cold dilute sulphuric acid. In fact, the attack is not very great at concentrations of 80 per cent and at temperatures as high as 100 deg. C. This is accounted for by the fact that the coating of lead sulphate that forms on the surface at first contact is practically insoluble in dilute sulphuric acid. In concentrated sulphuric acid, however, starting at about 80 per cent concentration, the solvent effect of the acid on lead sulphate increases very rapidly. The solvent effect of the concentrated acid is increased even more rapidly by the temperature factor, so that with concentrations of sulphuric acid approaching 100 per cent and at temperatures approaching the boiling point, the coating of lead sulphate has practically no protective effect. Lead is almost spontaneously changed into its sulphate under these conditions. The various corrosion tests that have been published bear out the above facts.

*Sulphurous acid* solutions readily attack most metals and consequently for the lower concentrations wood is generally used. Concentrations higher than 5 per cent are not often used, but Whittaker says that lead is permissible for this work.

*Waters, Saline.* The soluble phosphates such as those of the alkali metals almost entirely prevent the solution of lead. This is due to the formation of a protective layer of lead phosphate, one part of which requires about seven million parts of water to dissolve it. Carbonates and bicarbonates are also inhibitive, and for this reason it has been the custom in some localities to pass raw water supplies through a bed of chalk or limestone to reduce their corrosivity. A mere trace of carbonate is not sufficient entirely to prevent the solution of lead,

about four parts of calcium carbonate or magnesium carbonate to each 100,000 parts of water being required as a minimum.

Considering the solvent effect of the various solutions upon lead from the point of view of the acids present, it is found that salts of phosphoric acid exert the least action, and very slightly removed from them in the scale of activity are the carbonates and bicarbonates. The sulphides, chlorides and acetates cause increased action that is fairly similar, but the nitrates are conspicuous by a marked tendency to increase the action upon lead of the waters in which they are dissolved. Ammonium chloride, ammonium acetate and ammonium nitrate in solution have very marked actions, especially the last named, which is more active than distilled water containing a limited amount of dissolved air for equal durations of exposure. The remarkable way in which the ammonium salts and especially ammonium nitrate attack lead is no doubt due to the fact that these salts become largely hydrolyzed in aqueous solution and thus exhibit the properties of acids rather than of neutral salts. The rapid action of the nitrate solutions upon lead is ascribed to their oxygen content which is available for oxidizing purposes. Sodium silicate diminishes the corrosivity of water.

*Wood.* It has been known since very early times that some woods corrode lead. Unseasoned oak and moist oak are said to contain acids that readily attack lead. Pine is considered harmless.

# Nickel

### *A Corrosion Resistant So Effective That It Has Been Called a Semi-Noble Metal— Has Recently Become Available in Many Forms*

NICKEL has usually been thought of as a semi-noble metal, because of its resistance to chemical corrosion as well as its much higher cost than other structural metals. Notwithstanding this attitude, several chemical engineers and chemical manufacturers have seen promising possibilities of this metal and have begun to use it in equipment. Considerable difficulty was encountered at first in obtaining a satisfactory malleable variety of this metal, due probably to the fact that nickel retains its strength at much higher temperatures than iron or steel and hence is more difficult to work. Malleable nickel sheets and plate are now obtainable. These are fabricated into riveted equipment in practically the same manner as riveted steel equipment is built.

Large nickel castings are still being avoided by users, because of the difficulty in obtaining them free from porosity and similar imperfections. Molten nickel readily absorbs carbon monoxide, which is given off upon cooling, and it is to this property of nickel that the porosity of castings is attributed.

The advantages of nickel were recognized many years ago, but recent advances in the technology of this metal and its alloys have aroused increased interest among chemical engineers. Among the first to adopt nickel as a corrosion-resisting material was the central European housewife. She has been using nickel cooking utensils for 20 years or more. At first there was some hesitancy about using this metal, for nickel salts were known to be poisonous. Various investigators showed, however, that no harmful physiological effects could be expected.

*Electrodeposited Coatings of Nickel.* The chief applications of nickel deposition are the production of elec-

trolytic nickel and the electroplating of steel, brass, zinc and many alloys. The parts that are plated are usually stampings or castings and the coating is applied more for the purpose of improving their appearance than for affording a corrosion-resisting surface. Nearly all electroplated coatings are porous and hence do not completely protect the base metal. Nickel-plated iron will show signs of rust in a very short time when exposed to the weather. If a weather-resisting coating is desired, the iron or steel is first plated with zinc, after which the ornamental coating of nickel may be applied.

### Corrosion of Nickel by Various Reagents

*Acetic Acid.* Nickel is said to be as good as or better than copper for use with acetic acid. The presence of air or an oxidizing agent brings about solution of some of the copper and hence contamination of the acetic acid, but nickel seems to be resistant to acetic acid containing hydrogen peroxide.

*Acetylene.* When nickel is exposed to acetylene gas at temperatures ranging from 200 to 600 deg. C., it becomes decidedly brittle and a pitting action is evident.

*Acid sodium phosphate*, when molten, attacks nickel, forming a residue consisting entirely of the nickel and sodium pyrophosphates.

*Ammonium hydroxide* does not seriously attack nickel. It is not, however, recommended for use with this reagent, because there are less expensive metals that are equally suitable. The presence of oxygen and oxidizing agents is said to slightly accelerate corrosion.

*Ammonium azide* solution corrodes nickel anodes with the formation of a complex nickel azide deposit on the metal. Since gas is evolved at the anode, the corrosion efficiency in this electrolyte is considerably below normal.

*Ammonium Persulphate.* The analogy is pointed out between the solution of copper in this reagent without the evolution of gas and the reaction when copper is used as the anode in the electrolysis of a sulphate solution. The analogy is said to apply to nickel as well.

*Benzaldehyde*, when present in acids in contact with nickel, is said to affect materially the rate of corrosion.

*Benzoic Acid Vapors.* Nickel resists corrosion by benzoic acid vapors at about 250 deg. C. better than Monel metal or copper.

*Benzophenone* is supposed to exert a similar effect to that of benzaldehyde upon the rate of corrosion of nickel by acids.

*Calcium chloride* attacks nickel only very slightly.

*Carbon monoxide* combines with nickel at 50 to 80 deg. C. to form nickel carbonyl, a gas upon which is based the purification method of the Mond Nickel Co.

*Chloracetic acid* readily corrodes most of the common metals of construction. Nickel seems to be the least affected of any of them.

*Citric acid* does not materially affect nickel when in contact for only a short time. On long exposure, however, some corrosion is evident.

*Fatty acids*, with the exception of formic acid, do not noticeably attack nickel.

*Ferric chloride* solutions at elevated temperatures seriously attack nickel with the formation of ferrous and nickel chlorides.

*Formic acid* appreciably corrodes nickel, which is not recommended for handling this acid.

*Halogens*, when dry, do not affect nickel, and when moist, attack it only slightly. Most of the nickel alloys,

however, are not recommended for use with the halogens.

*Hydrochloric acid* slowly dissolves nickel and most of its alloys. It is used as an etching reagent for this metal in metallographic work. The presence of an oxidizing agent accelerates corrosion.

*Hydrogen peroxide*, when present with dilute hydrochloric and sulphuric acids, accelerates the corrosion of nickel. Its presence in acetic acid, however, does not seem to affect nickel's resistance to corrosion.

*Lactic acid* affects most of the metals in much the same way as acetic acid. Although nickel withstands this acid satisfactorily, aluminum or wood is usually used for handling the edible grades.

*Magnesium Chloride.* Hale and Foster determined that nickel was only slightly attacked by this reagent. Some of the data has been reproduced in the Bureau of Standards circular on nickel.

*Nitric acid* rapidly dissolves nickel. In contact with concentrated nitric acid it becomes passive like iron. If a piece of nickel is dropped into fuming nitric acid, it may be violently attacked, may become passive or may be disintegrated to a gray, magnetic powder.

*Nitric oxide*, when bubbled through water in which finely divided nickel is suspended, is converted to nitrogen with the formation of nickel oxide. Nickel becomes incandescent in an atmosphere of nitric oxide at 200 deg. C.

*Nitrobenzene*, when present in acids, accelerates the solution of nickel.

*Nitrogen* at 300 deg. C. attacks nickel to form a volatile nitride. Inasmuch as this nitride attacks platinum very strongly, rendering it brittle and crystalline, no nickel should be present in the same heated atmosphere with platinum thermocouples or dishes.

*Oxalic acid* attacks nickel appreciably only on long exposure. The action is thought to be due to the presence of dissolved oxygen and the subsequent solution of the products of corrosion.

*Oxygen* does not affect nickel at ordinary temperatures. At a red heat it coats nickel with a green-colored oxide. When heated, nickel wire burns in an oxygen atmosphere. Metallic nickel which has been prepared by reduction of its oxide with hydrogen is pyrophoric.

*Phenols* from low-temperature tar do not seriously attack nickel.

*Photographic Solutions.* Nickel is suitable only for developing and washing apparatus. No metal has been found that is satisfactory for handling toning solutions.

*Picric Acid.* The action of this chemical, when molten, upon various metals, including nickel, is described by Saposchnikov. Both aluminum and iron withstand the action better than nickel.

*Potassium hydroxide*, either fused or in aqueous solution, has no effect upon nickel.

*Sodium Acetate.* White has shown that nickel is passive to corrosion when used as an anode in the electrolysis of this salt solution.

*Sodium carbonate*, as determined by Hale and Foster, has no corrosive effect upon nickel.

*Sodium chloride* was found to have no effect upon nickel by Hale and Foster. When a nickel wire is suspended in a solution of this salt over mercury and the other end of the wire is connected with the latter to complete the circuit, the nickel wire is converted to crystalline $Ni(OH)_2$, sodium hydroxide being generated in the solution.

*Sodium hydrosulphite* in neutral solution does not attack nickel.

*Sodium hydroxide,* either fused or in aqueous solution, has no effect upon nickel.

*Sodium Nitrate.* White has shown that nickel is passive to corrosion when used as an anode in the electrolysis of this salt solution.

*Sodium sulphate* solution, when used as an electrolyte, was shown to have no effect upon a nickel anode.

*Sodium tartrate* solution, when used as an electrolyte, was shown by White to not affect the nickel anode.

*Steam* does not warp or erode nickel and most of its alloys.

*Sulphuric acid* dissolves nickel slowly. Its alloys are also affected by this acid to some extent. The presence of hydrogen peroxide in the acid is said to materially accelerate the corrosion.

*Tartaric acid* corrodes nickel appreciably only on long exposure, and the effect is believed to be due more to the influence of dissolved oxygen than to the action of the acid alone.

*Thionyl chloride* does not react with nickel at 150 to 200 deg. C., according to North and Hageman.

*Water.* Studies relative to the effect of nickel and other metals upon water have been made by Van Rijn and by Jorissen. Very pure water is said to attack nickel very slightly, but ordinary fresh water, sea water or mixtures of the two do not affect nickel at ordinary temperatures. Although nickel withstands some mine waters fairly well, nickel alloys are generally used for mine water pumps, because the chemical and physical properties of the alloys may be adjusted to suit special conditions.

# Tin

### Due Largely to Its Remarkable Resistance to Water and Atmospheric Corrosion, Tin Finds Wide Application in the Food Industry

TIN is a white, lustrous metal that melts at 232 deg. C. and has a specific gravity of 7.293 at 13 deg. Its specific heat is 0.05363 at 0 deg., 0.05549 at 54 deg. and 0.05690 at 97.6 deg. When broken, it exhibits a fibrous structure and when bent emits a distinctive creaking sound due to friction between the moving crystals. It is malleable and can easily be rolled or hammered into foil. At 100 deg. it may be drawn into wire, but at 200 deg. it becomes so brittle that it may be powdered. On the other hand, at low temperatures it falls to a coarse powder called "gray tin." This is the stable form of tin below 18 deg., although at temperatures only slightly below this the change from ordinary tin takes place very slowly.

This metal is susceptible to what is called by various authors "tin pest," "tin plague" or "strain disease." In some of its effects it is similar to the formation of "gray tin." However, the metal is susceptible to this "infective disease" at temperatures considerably above which the gray modification does not form. Contact with an infected piece of tin is all that is necessary to transfer the disease to clean metal. This disease was first reported by von Hasslinger and has been described in much detail by Cohen. In 1910 Berger reviewed sundry investigations which had been made of this disease, and in 1918 Schultz reviewed the knowledge regarding this and other diseases of metals. Krynitzky has also studied the decomposition of various metals,

and his views coincide with those of previous authors in that the disease is primarily due to strain. He states that cold-working of the metal should always be followed by annealing.

Tin is widely used in alloys, for the manufacture of tinfoil and for coating other metals such as copper and iron to render them more resistant to corrosion. Tin, of itself, is very resistant to atmospheric corrosive agents; in fact water affects it hardly at all and at ordinary temperatures there is no tendency toward oxidation. This metal would serve admirably, therefore, as a protection to sheet iron or steel were it not for the fact that it is electronegative to iron and strongly accelerates its corrosion in the presence of atmospheric electrolytes if the coating is not continuous. It dissolves rather slowly in most of the acids. It readily reacts, however, with nitric acid to form metastannic acid. It also reacts with aqueous solutions of the alkalis to form stannite and stannate salts. It is susceptible to the acids occurring in canned foods, particularly in the presence of oxygen.

## CORROSION BY SPECIFIC REAGENTS

*Acetic Acid.* Calcott and Whetzel have reported several tests in which block tin was subjected to the attack of 20 per cent, 60 per cent and 100 per cent acetic acid at 25 deg. and the respective boiling points of the solutions. Although their data were obtained by one of their early corrosion methods, it clearly indicates that acetic acid may be safely handled in tin, at least up to 60 per cent concentration and probably somewhat higher at 25 deg., whereas boiling acetic acid should not be handled in tin in concentrations very much over 20 per cent.

An early investigation of the effect of vegetable acids on tin and lead was made by Hall, who found that 5.75 per cent acetic acid attacks tin, lead and their alloys in the presence of oxygen. His investigation included susceptibility of tinfoil to this acid, but on analyzing the various samples of foil, the majority of them contained 70 per cent or more of lead. Fouw determined the susceptibility of tin to very much more dilute concentrations of the organic acids and has reported that 0.1 and 0.01 normal solutions of acetic acid attack tin rapidly in the air, but scarcely at all in vacuo or in carbon dioxide. When one reviews the work under a later heading, "Vegetables, Canned," he will see that the presence of oxygen is still considered the principal cause of corrosion of this metal by organic acids. The statement of Salkowski that tin does not dissolve in acetic acid in the presence of hydrogen peroxide would seem to need further investigation, particularly since Lehmann has reported the accelerating corrosive effect of nitrates in these same acids.

*Ammonium Hydroxide.* The weight of evidence is contrary to the susceptibility of tin to ammonia.

*Carbon dioxide* in solution does not affect tin.

*Chromic Acid.* When the acidity is sufficiently high the determining factor of corrosion is diffusion.

*Citric acid* attacks tin quite rapidly in contact with the air, but scarcely at all when the air is excluded.

*Foods.* See "Organic Acids" and "Vegetables, Canned."

*Hydrochloric Acid.* Tin does not dissolve very rapidly in dilute solutions of hydrochloric acid.

*Iodine.* Tin is readily susceptible to attack by iodine, whether in the form of solution or vapor.

*Milk.* Sweet milk has no effect upon pure tin or tin

plate, but sour milk undoubtedly corrodes tin quite readily in the presence of air.

*Nitric Acid.* This acid readily reacts with tin.

*Organic Acids.* Since tin is widely used in coating tinned iron for use in containers for canned foods, a great deal of attention has been given to its susceptibility to organic acids. Lehmann, who has done considerable work on the toxicity of metals, has stated that very little, if any, tin is dissolved by the dilute fruit and vegetable acids when oxygen is excluded. He warns against the presence of nitrates, however, since they serve as oxidizing agents and affect tin containers as if they were exposed to air. He is in favor of lacquering the inside of tins to postpone contact with organic acids.

*Oxalic Acid.* The action of 0.1 and 0.01 normal solutions of oxalic acid on tin has been investigated by Fouw, who states that they attack tin in the presence of air, but scarcely at all in vacuo or in carbon dioxide.

*Oxygen and Oxidation.* A careful investigation of the action of oxygen on tin, other metals and their alloys has been performed by Jordis and Rosenhaupt. These authors state that no oxidation of tin takes place at ordinary temperatures. At 100 deg. C., however, the oxidation begins. Below 200 deg. C. it is oxidized more slowly in moist than in dry oxygen and forms a partially protective coating. Oxygen has an accelerating effect upon the corrosive action of most reagents.

*Sodium chloride* does not corrode tin.

*Sodium Hydroxide.* Since tin forms basic salts, it is somewhat susceptible to attack by sodium hydroxide solutions.

*Stannous chloride* dissolves tin.

*Sugar.* The presence of sugar in canned foods serves to protect the tin from corrosion by vegetable acids, according to Lehmann and Carles. The inhibitory action of sugar, according to the former author, applies also to copper and iron. Carles has stated that when tomatoes are not of late season or first quality the acidity is greater, owing to the lack of sugars and pectin substances, and he states that such tomato pulps have more action on tin containers.

*Sulphuric Acid.* Appreciable action. Accelerated by oxidizing agents.

*Vegetables, Canned.* Ever since tin-coated cans have been used for the preservation of food materials, occasional articles have appeared in the literature telling of the amount of tin that has been found in the food. In 1912 Coerbergh reported the results of analysis of more than seventy cans of spinach, and he stated that the product of one maker is likely to contain greatly varying amounts of tin. He found that in the cans that were not varnished to give added protection the amount of tin was usually less than 126 mg. per kg. of contents. In the varnished cans the content of tin was always lower. Contrary to other authorities Coerbergh says that the presence of air or nitrates in the canned spinach bears no relation to the amount of tin found. Rossee and Morgenstern have stated that canned foods always contain some tin, but usually in small amounts. Large amounts are dissolved only when the can is left open for some time. These authors state that tin forms insoluble compounds with the vegetable substances and is not redissolved by the gastric juice, hence the presence of small amounts of tin in foods is not thought to be harmful.

*Water.* Even the purest water has practically no solvent effect upon pure tin.

# Zinc

### Not a Corrosion-Resistant Metal but One So Widely Used Industrially That Its Chemical Properties Are of Great Importance

ALTHOUGH zinc is far from being a corrosion-resistant metal, it is very widely used industrially. It rarely enters the construction of chemical equipment except in the form of an alloy, but owing to the fact that it is electropositive to iron, it is widely used as a protective coating for iron against the weather. Several methods have been devised for applying coatings of zinc—namely, cowperizing, electrogalvanizing, galvanizing, lohmannizing, spraying by the Schoop process and sherardizing.

In practice the corrosive agents most frequently encountered by zinc are the atmosphere and various waters. Zinc slowly corrodes in the atmosphere to form a relatively non-adherent film of basic carbonate. Consequently a thoroughly protective coating is not formed. This coating is protective against oxidation but not against erosion. If only the zinc surface of a galvanized sheet is exposed, the corrosion takes place relatively slowly. When, however, the coating is pierced and the iron is exposed, electrolytic action begins and the zinc disappears rapidly. The base metal is unaffected while this action proceeds, but upon the disappearance of the last of the zinc coating, the iron will begin to corrode. In galvanized water pipes the corrosion progresses in a similar manner. The solution of zinc takes place very slowly until the iron base metal is exposed and then it is only a short time before corrosion takes place as in an ordinary pipe.

Zinc melts at about 420 deg. C. Castings made at slightly above this temperature are comparatively malleable, but when the metal is poured at a high temperature, the castings are brittle and crystalline. Above its melting point, zinc is readily oxidized by contact with the air. In fact, it readily burns with an intense white flame in a current of air at only slightly above its melting point.

*Acetic acid* reacts very readily with zinc. On the other hand, some of the zinc alloys are very resistant to this acid.

*Acids* readily dissolve zinc.

*Ammonia.* When zinc is heated in an atmosphere of dry ammonia, it readily forms a nitride at about 600 deg. C.

*Ammonium Hydroxide.* Immersion of zinc in ammonium hydroxide results in a slow reaction in which a small but perceptible amount of hydrogen is evolved.

*Calcium Chloride.* This reagent slowly attacks zinc.

*Citric Acid.* Even such a weak organic acid as citric acid readily dissolves zinc.

*Ether.* It is evident that ether plays some part in the corrosion of zinc by other chemical compounds, such as, for instance, sulphur chloride and dichlormethylarsine. Domanicki has reported a series of experiments in which he has found that ether accelerates the reaction of sulphur chloride with such metals as zinc, aluminum, tin and bismuth, which react to give chlorides that readily form etherates. Zappi describes the attack on zinc and magnesium by dichlormethylarsine in ether solution and he mentions that the reaction is particularly active if water is present.

*Hydrocyanic Acid.* Pure zinc is said to be highly resistant to pure liquid hydrocyanic acid.

*Iodine.* Iodine vapors such as those that might be present in a desiccator apparently do not affect zinc to any great extent, although when metal surfaces that have been exposed to these vapors are treated with water, measurable amounts of zinc iodide are obtained. Matignon also tried the effect of iodine on various metals, although he used a spot of iodine on the metal surface instead of the vapor. Zinc, among other metals, was affected and showed liquid droplets of deliquescent salt as a result of the reaction.

*Nickel Salt Solutions.* In reporting their extensive study on the properties of zinc, Centnerszwer and Drukker make the statement that zinc displaces nickel from its salts with some difficulty. It is obvious from this that zinc must be attacked to some extent.

*Nitrobenzene,* when present with zinc in an acid solution, rapidly accelerates the reaction. This is more or less true with most of the organic reducible compounds.

*Oxalic Acid.* The attack of oxalic acid on metals is chiefly of importance in connection with the corrosion of metal containers. Fouw recently investigated the action of 0.1 per cent and 0.01 per cent normal solutions of oxalic, as well as several other organic acids, on the metals used in containers of canned goods. Although this acid attacks tin and dissolves the corrosion product of this metal, it has scarcely any action on zinc. In fact, Fouw claims that it even inhibits the action of other acids on zinc.

*Sodium Chloride.* Several authors concur in the statement that zinc is corroded by sodium chloride. Most of them, however, state that the corrosion is small.

*Sodium hydroxide* appreciably affects zinc surfaces.

*Sulphuric Acid.* While extremely pure zinc dissolves very slowly, the commercial metal is attacked readily.

*Waters, Ordinary.* Since zinc is used very widely for the protection of more susceptible metals against moisture and air, it is not surprising that a great deal of work has been done in the susceptibility of this metal to these two agents. More work seems to have been done, in fact, on the resistance of zinc to water than to any other corroding agent. The general consensus is that zinc is susceptible to all waters to a certain extent. In fact, at slightly elevated temperatures it dissolves with the evolution of measurable amounts of hydrogen. At ordinary temperatures it is slightly soluble in water and is found in practically all water supplies that are conducted through pure zinc or zinc-coated conduits. Zinc is particularly soluble in highly carbonated waters, somewhat less soluble in distilled water, and only very slightly soluble in tap water.

*Zinc Chloride.* The use of zinc chloride solution for removing zinc from zinc-coated articles has been patented by Weber, who says that the solution should preferably have a basicity of about 1 per cent at the beginning of the treatment and about 3 per cent at the end. Hydrochloric acid is then added to restore it to its original condition for further use.

---

## Tabular Presentation of Chemical and Physical Properties of Corrosion-Resisting Alloys

A COMMITTEE of members of the American Society for Testing Materials, under the chairmanship of Jerome Strauss, materials engineer of the U. S. Naval Gun Factory, Washington, D. C., has made a systematized compilation of the available data regarding those alloys having iron, nickel or copper as the predominating element and offering resistance to various destructive agencies. The tables they have prepared provide a wealth of information in convenient form on the physical and chemical properties of these metals. Part of this collection is of the greatest value to the chemical engineer, and has been incorporated in the tables herewith.

The data desired were those in the possession of the manufacturers of the various metals; they were so assembled as to give to the prospective user a broad survey of the field from which he might, as a preliminary step, select several metals offering the greatest promise for a specific purpose. Further inquiry of the manufacturer, coupled with some form of comprehensive testing, would unquestionably be required to reach a final decision. Questionnaires were mailed to approximately sixty manufacturers. In the haste of selection some were included whose products would not properly fall within the scope of this survey or whose products had not reached a satisfactory stage of commercial development; others did not desire to have their materials listed; in general, however, the response to the committee's request, regardless of actual submission of data, was exceptionally good, replies having been obtained from well above 90 per cent of the original list.

The compilation of the data on the resistance offered to corroding media presented particular difficulty. Information concerning the attack by the most common acids and alkalis was originally requested for 0.5 per cent, 20 per cent and concentrated solutions. Data submitted in quantitative and hence the most valuable form were not always available in the first two specific concentrations. The headings in the tables were therefore changed to "Very Dilute" and "Moderate Dilution" as being somewhat more representative. In all but a very few cases, qualitative comments were the same for both dilutions, so that the change of headings is in no way apt to be misleading. But in those few instances where differences in behavior are recorded for "very" and "moderate" dilution, the manner in which the data were requested must be borne in mind.

Very few took notice of the request to record, in the submission of qualitative corrosion data, their understanding of the terms "Excellent," "Good," "Fair" and "Poor," which were suggested as a uniform medium of expressing opinion on these matters. In fact in some cases other expressions than the above were employed, and it was necessary to convert them to one of the four preferred terms as well as could be done. This was accomplished by using as a criterion the following definitions, which were the only detailed ones submitted, and which are truly representative of the thoughts that originally dictated the preparation of the questionnaire:

*Excellent.* Resistance to corrosion of such a degree in laboratory and service tests that a long life of years is obtained.

*Good.* Resistance to corrosion of such a degree in laboratory and service tests that commercially long life is obtained.

*Fair.* Resistance to corrosion of such a degree in laboratory and service tests that the material may be used where cost is not a consideration.

*Poor.* Resistance to corrosion of such a degree in laboratory and service tests that the material is useless.

## Table II—Thermal, Electrical and Corrosion Data on Corrosion-Resistant, Heat-Resistant and Electrical-Resistance Alloys

| Manufacturer | Designation of Material | Form of Material | Mean Therm. Cond. Room Temp. C.G.S. Unit | Mean Coeff. Therm. Exp. 0-100° C × 10⁵ | Max. Temp. for Continuous Oper. in Air, Deg. C. | Sulphuric Acid Very Dilute | Sulphuric Acid Moderate Dilution | Sulphuric Acid Concentrated | Nitric Acid Very Dilute | Nitric Acid Concentrated | Hydrochloric Acid Very Dilute | Hydrochloric Acid Moderate Dilution |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Allegheny Steel Co. | Ascoloy | Wrought | a | | 800 | Poor | Poor | Good | Good $c$ | Excellent | Poor | Poor |
| | Carp. Stainless | Wrought | | | | Poor | Poor | Poor | Excellent | Excellent | Poor | Poor |
| Carpenter Steel Co. | Carp. Rustless | Wrought | | 0.99 | 1000 | Poor | Poor | Poor | Excellent | Excellent | Poor | Poor |
| | 30 per cent Nickel Steel | Wrought | | | | | | | | | | |
| | Corrosion-Resistant Steel | | | | | | | | | | | |
| Crucible Steel Co. | No. 2600 Metal | Wrought | | | | $j$ | $k$ | $o$ | | $q$ | | |
| | Resistal No. 4 | Wrought | | 1.61 | 980 | | | | | | | |
| | Resistal No. 7 | Wrought | | 1.61 | 1150 | | | | | | | |
| | Resistal No. 8 | Wrought | | 1.61 | | $x$ | $y$ | $w$ | | | | |
| Cyclops Steel Co. | No. 17 Metal | Wrought | | 1.68 | | Good | Good | | Excellent | | Fair | Fair |
| Firth-Sterling Steel Co. | S-less Stainless Steel | Wrought | 0.0445 | 1.09 | | Poor | Poor | Poor | Excellent | Excellent | Poor | Poor |
| | S-less Stainless Iron | Wrought | | | | | | | | | | Good (16 per cent acid) |
| | Delhi Tough Iron | Wrought | | | 1000 | Fair | Fair | Good | Excellent | Excellent | Poor | Poor |
| Ludlum Steel Co. | Deli Hard | Wrought | | | 930 | Poor | Poor | Good | Excellent | Excellent | | Poor |
| | Silcrome | Wrought | | | 950 | Poor | Poor | Good | Excellent | Excellent | Poor | Poor |
| | Silcrome, Grade F | Wrought | | | 930 | | | | | | | |
| | Stainless Steel (Low C) | Wrought | | | | Fair | Fair | Poor | Excellent | Excellent | Good | Good |
| The Midvale Co. | Stainless Steel (Med. C) | Wrought | | | | Fair | Fair | Poor | Excellent | Excellent | Good | Good |
| | Stainless Steel (High C) | | | | | Fair | Fair | Poor | Excellent | Excellent | Good | Good |
| Vanadium Alloys Steel Co. | Stainless Steel | Wrought | | | | | | | | | | |
| Calorizing Co. | Calite A | Cast | | ac | 1150 | | | | | | | |
| | Calite B | Cast | | ac | | | | | | | | |
| Chrobaltic Tool Co. | Fire Armor | Cast | | 1.4 | 1290 | | | | | | | |
| Michigan Steel Casting Co. | Misco Metal | Cast | | | | | | | Poor | Poor | Fair | Fair |
| | Nichrome | Wrought | 0.033 | 1.22 | | | | | | | | |
| | Nichrome | Casting | 0.033 | | 1000 | | | | | | | |
| | Nichrome III | Wrought | 0.033 | 1.32 | 1100 | | $ag$ | | | | | |
| | Nichrome IV | Wrought | 0.033 | 1.32 | 1150 | | $ag$ | | | | | |
| | No. 193 Alloy | Wrought | | | 600 | | | | | | | |
| Driver-Harris Co. | Cimet | Wrought | 0.082 | | 1150 | | | | | | | |
| | Cimet | Cast | | 1.53 | 1150 | Poor | Poor | Good | Excellent | Excellent | Poor | Poor |
| | Advance | Wrought | | | 900 | | | | | | | |
| | Manganin | Wrought | | | | | | | | | | |
| Cutler Steel Co. and Driver-Harris Co., licensees of Electro-Metallurgical Co. | Chrome Iron, Duraloy, Cimet | Wrought & Cast | aj | 1.19 | 1100 | Fair | Poor | Poor | Excellent | Excellent | Poor | Poor |
| Haynes Stellite Co. | Stellite | Cast | | 1.36 | 1000 | | Good | Good | | Excellent | | Poor |
| The Duriron Co. Pacific Foundry Co. | Duriron | Cast | 0.125 | 2.92 | | ao | ao | ao | ao | ao | ao | ao |
| Bethlehem Foundry & Machine Co. | Corrosiron | Cast | | | | Excellent | Excellent | Excellent | Excellent | Excellent | Fair | Good |
| | Karma | Wrought | | 1.35 | 1100 | Excellent | Excellent | Good | Good | Good | Good | Good |
| | Elaleo Ravo | Wrought | | 1.35 | 1100 | Excellent | Excellent | Good | Good | Good | Good | Good |
| | Elaleo Calido | Wrought | | 1.3 | 1000 | Excellent | Excellent | Good | Good | Good | Good | Good |
| | Elaleo Comet | Wrought | | 1.6 | 700 | Good | Good | Fair | Fair | Poor | Fair | Fair |
| Electric Alloy Co. | Elaleo Pure Nickel | Wrought | 0.142 | 1.3 | 650 | Good | Good | Fair | Fair | Poor | Good | Good |
| | Elaleo Manganese Nickel | Wrought | | 1.3 | 650 | Good | Good | Good | Fair | Poor | Good | Good |
| | Elaleo Magno | Wrought | 0.065 | 1.3 | 650 | Good | Good | Good | Fair | Poor | Good | Good |
| | Elaleo Ideal | Wrought | | | 500 | | | | | | | |
| | Chromel A | Wrought | | 1.6 | 1150 | | ca | cb | | cc | | cd |
| | Chromel B | Wrought | | 1.6 | 1100 | | | | | | | |
| | Chromel C | Wrought | | 1.6 | 1000 | | | | | | | |
| Hoskins Manufacturing Co. | Chromel D | Wrought | | | 600 | | | | | | | |
| | Chromel Alloy No. 502 | Cast | | 1.6 | | | | | | | | |
| | Copel | Wrought | | | | | | | | | | |
| | Alloy No. 484 | Wrought | | | 425 | | | | | | | |
| International Nickel Co. | Monel Metal | Wrought & Cast | 0.06 | 1.5 | 800 | as | as | as | as | | | |
| | Nickel (Commercially Pure) | Wrought & Cast | 0.140 | 1.3 | 1300 | | | aw | | Poor | aw | aw |
| American Metal Products Co. | Ampco | Wrought & Cast | | | | | | Good | | Poor | Good | Good |
| Aterite Co., Inc. | Aterite | Wrought | 0.077 | 1.65 | | Excellent | Excellent | Excellent | Poor | Poor | Good | Good |
| | | Cast | 0.045 | 1.48 | | Excellent | Excellent | Excellent | Poor | Poor | Not recommended | |
| Chapman Valve Mfg. Co. | Davis Metal | Cast | 0.045 | 1.44 | | bf | bf | Excellent | | | bf | |
| Chase Metal Works | Naval Brass | Wrought | | 2.14 | | Good | Fair | | Poor | | Fair | Fair |
| | Admiralty Tubing | Wrought | | 2.02 | | Good | Fair | | Fair | Poor | Fair | Poor |
| | Commercial Bronze Rod | Wrought | | 1.85 | | Excellent | Good | | | | Good | |
| Curtis Bay Copper & Iron Works | 18-per cent Nickel Silver | Wrought | | | | Good | | Poor | | Poor | Good | Fair |
| | Everbrite No. 90 | Wrought | | | | | | | | | | |
| | Everbrite No. 92 | Wrought | | | | | | | | | | |
| Dupont Engineering Co. | Everdur No. 50 Metal | Wrought & Cast | | 1.7 | | | bi | bi | Poor | Poor | | bi |
| Frontier Bronze Corp. | Titanium-Aluminum Bronze No. 1 | Cast | | 1.71 | | Good | Good | Good | | | Good | Good |
| | Titanium-Aluminum No. 5 | Cast | | 1.71 | | Good | Good | Good | | | Good | Good |
| | Naval Brass | Wrought | | | | | | | | | | |
| Scovill Mfg. Co. | Admiralty Metal | Wrought | | | | | | | | | | |
| | Admiralty Nickel | Wrought | | | | | | | | | | |
| | Spring Oreide | Wrought | | | | bk | bk | | | | | |
| Standard Calorimeter Co. | Illium | Cast | | 1.35 | | bm | bm | bm | bm | bm | bm | bm |

*a*   Approximately 1/16 that of copper.
*c*   Attacked by extremely dilute solutions only.
*d*   Loss in mg. per sq.in.; 5 per cent NaCl, aerated, 200 hr. = 3.1.
*e*   Loss in mg. per sq.in.; SO₃ + steam, 23 days = 987.
*j*   Loss in mg. per sq.in.; 5 per cent H₂SO₄, 90° C., 14 hr. = 10.0.
*k*   Loss in mg. per sq.in.; 10 per cent H₂SO₄, 90° C., 7 hr. = 13.4.
*m*   Loss in mg. per sq.in.; glacial acetic, 90—100° C. 2 hr. = 4.7.
*n*   Loss in mg. per sq.in., saturate boiling NH₄Cl, 3½ hr. = 3.8.

    15 per cent lactic acid, 48 hr., 90—100° C. = 21.8.
    2 hr. at 2000° F. (atmosphere not stated) = 100.
    7 hr. at 1300° F. (atmosphere not stated) = 2.75.

*o*   Loss in mg. per sq.in., 4 days, 80° C.
    10 per cent Oleum ........ 1.6     100 per cent H₂SO₄ ...... 0.9
    20 per cent Oleum ........ 1.2     66 Be. H₂SO₄ ........... 0.3
    30 per cent Oleum ........ 1.2     60 Be. H₂SO₄ ........... 19.9
                         50 Be. H₂SO₄ ........... 85.7

*q*   Loss in mg. per sq.in., 4 days, 80° C., 96 per cent = 0.3.
*r*   Loss in mg. per sq.in., 5 hr., 80° C., 20 Be HCl.= 140.6.
*s*   Loss in mg. per sq.in., 4 days, 80° C., glacial acetic = 0.3.

*t*   Loss in mg. per sq.in., 8 days, room temperature = 0.03.
*u*   Loss in mg. per sq.cm. per day = 0.00015—0.0422.
*w*   Loss in mg. per sq.in., 6 hr., 90—100° C. = 0.95.
*w*   Loss in mg. per sq.in., 7 hr., 90° C., 20 per cent H₂SO₄. = 12.4.
*x*   Loss in mg. per sq.in., 5% H₂SO₄, 90° C., 14 hr. = 6.3.
*y*   Loss in mg. per sq.in., 10% H₂SO₄, 90° C., 7 hr. = 8.4.

*ac*   0.5 per cent at room temperature to 1500° F. (total expansion).
*ag*   Resistance to various corrosives similar to Nichrome, but somewhat superior.
*aj*   Approximate one-half that of low-carbon steel.
*an*   Value at 18° C.
*ao*   Losses in inches thickness per mo. × 10⁶ (room temperature): H₂SO₄ 0.5%, 0.57; 20%, 0.39; concentrated, 0.16.   Nitric Acid 0.5%, none; 20%, 0.17; concentrated 0.15.   Hydrochloric Acid 0.5%, 12.0; 20%, 667; concentrated, 1822.   Acetic Acid 0.5%, none; concentrated, 0.15.   Mine waters, 0.63.
    Losses in inches thickness per mo. × 10² (90° C): Sulphuric acid 0.5%, 13.0; 20%, 7.1; concentrated, 0.63.   Nitric Acid 0.5%, 0.28; concentrated, 16.0.   Hydrochloric acid, 0.5%, 140; 20%, 2800; concentrated, 10,170. Acetic acid 0.5%, none; concentrated, 0.23.

## Table II—Thermal, Electrical and Corrosion Data on Corrosion-Resistant, Heat-Resistant and Electrical-Resistance Alloys—(Continued)

| Manufacturer | Acetic Acid — Very Dilute | Acetic Acid — Concentrated | Sodium Hydroxide — Very Dilute | Sodium Hydroxide — Concentrated | Ammonium Hydroxide — Moderate Dilution | Ammonium Hydroxide — Concentrated | Sea Water | Sea Air | Moist Atmosphere | Moist Sulphurous Atmosphere | Mine Waters | Chlorine in Aqueous Solution | Gases Containing Carbon Monoxide |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Allegheny Steel Co. | | Excellent | Excellent | Excellent | Excellent | Excellent | *d* Good | Excellent | Excellent | *e* Poor | | Good | Excellent |
| Carpenter Steel Co. | Excellent | Excellent | Excellent | Excellent | Excellent | Excellent | Excellent | Excellent | Excellent | Excellent | | Poor | Excellent |
| Crucible Steel Co. | | *m* *s* *v* | | | | | *t* | | Excellent | | *u* | | |
| Cyclops Steel Co. | Excellent | | Excellent | Excellent | Excellent | | Excellent | Excellent | Excellent | Excellent | Good | Fair | Good |
| Firth-Sterling Steel Co. | Good | Excellent | Excellent | Excellent | Excellent | Excellent | Good | Excellent | Excellent | Poor | | Poor | |
| | Excellent | | Excellent | Excellent | Excellent | Excellent | | | | | | | |
| | Excellent | Good | Good | Excellent | Excellent | Excellent | Excellent | Excellent | Excellent | Excellent | Excellent | | Excellent |
| | Excellent | Good | Excellent | Excellent | Excellent | Excellent | Excellent | Excellent | Excellent | Excellent | Excellent | | Excellent |
| Ludlum Steel Co. | Excellent | Good | Good | Good | Good | Good | Poor | Poor | Poor | Poor | Excellent | Poor | Excellent |
| The Midvale Co. | | | | | | | Excellent | Excellent | Excellent | | | | |
| | | | | | | | Excellent | Excellent | Excellent | | | | |
| | | | | | | | Excellent | Excellent | Excellent | | | | |
| Vanadium Alloys Steel Co. | | | | | | | | | | | | | Good |
| Calorizing Co. | | | | | | | | | | | | | |
| Chrobaltic Tool Co. | | | | | | | | | | | | | |
| Michigan Steel Casting Co. | Poor | Poor | | | Excellent | Excellent | | | Excellent | | Excellent | | |
| | Poor | Poor | | | Excellent | Excellent | | | Excellent | | Excellent | | |
| Driver-Harris Co. | | | | | | | Excellent | Excellent | Excellent | | Excellent | | |
| Cutler Steel Co. and Driver-Harris Co., licensees of Electro-Metallurgical Co. | Good | Good | Good | Good | Good | Good | Excellent | Excellent | Excellent | Good | Excellent | Poor | Excellent |
| Haynes Stellite Co. | | Excellent | Excellent | Excellent | Excellent | Excellent | Excellent | Excellent | Excellent | Fair | Excellent | Fair | |
| The Duriron Co. | *ao* | *ao* | | | | | None | None | None | Slight tarnish | *ao* | | |
| Pacific Foundry Co. | | | | | | | | | | | | | |
| Bethlehem Foundry & Machine Co. | Excellent | Excellent | Excellent | Excellent | Excellent | Excellent | Excellent *ap* | Excellent *ap* | Excellent *ap* | Excellent | Good | Fair | |
| | Excellent | Good | Excellent | Good | Excellent | Good | Excellent | Excellent | Excellent | | | Fair | |
| | Excellent | Good | Excellent | Good | Excellent | Good | Excellent | Excellent | Excellent | | | Fair | |
| | Excellent | Good | Excellent | Excellent | Excellent | Excellent | Excellent | Excellent | Excellent | | | Fair | |
| Electric Alloy Co. | Good | | Excellent | Excellent | Excellent | Excellent | Fair | Fair | Fair | | | Fair | |
| | Good | Good | Excellent | Excellent | Excellent | Excellent | Excellent | Excellent | Excellent | | | Fair | |
| | Good | Good | Excellent | Excellent | Excellent | Excellent | Excellent | Excellent | Excellent | | | Fair | |
| | Good | Good | Excellent | Excellent | Excellent | Excellent | Excellent | Excellent | Excellent | | | | Fair |
| | | *cf* | | | | | | | | | | | |
| Hoskins Manufacturing Co. | | | | | | | | | | | | | |
| International Nickel Co. | *aw* | *aw* | | Excellent | *as* *aw* | *as* *aw* | | Excellent | Excellent | Fair | Excellent *ay* | Good | Excellent |
| American Metal Products Co. | Good | Good | Excell. nt | Excellent | Good | Fair | Excellent | Excellent | Excellent | Fair | Excellent | Fair | Excellent |
| Aterite Co., Inc. | Good | Good | Excellent | Excellent | Fair | Fair | Excellent | Excellent | Excellent | Excellent | Excellent | | |
| | | | | | *bf* | | Excellent | Excellent | Excellent | Excellent | | *bf* | |
| | | | Good | | | | Excellent | Excellent | Excellent | Good | | | |
| Chase Metal Works | | | Good | | | | Excellent | Excellent | Excellent | Fair | Poor | | |
| | | | Good | | Good | | Good | Good | Excellent | Excellent | | | |
| Curtis Bay Copper & Iron Works | Good | Good | Good | Good | Good | Good | Good | Good | Excellent | Fair | | Poor | |
| Dupont Engineering Co. | Excellent | Excellent | Excellent | Excellent | Fair | Fair | *bi* | Excellent | Excellent | Excellent | *bi* | *bi* | |
| Frontier Bronze Corp. | | | | | | | Good | Good | Good | | | | |
| | | | | | | | Good | Good | Good | | | | |
| Standard Calorimeter Co. | | *bm* | Excellent | Excellent | Excellent | Excellent | Excellent | Excellent | Excellent | Excellent | Excellent | Poor | Excellent |

*ap* Surface rusts.

*as* Monel Metal—Losses in inches thickness per mo. × 10² (room temperature): Sulphuric acid 0.53%, 0.152; 25%, 0.114; 93%, 1.65. Anhydrous NH₃, 0.016. Same thing agitated but not aerated: Sulphuric acid 1%, 0.009—0.031; 20%, 0.025; 93%, 0.44—0.18. Nitric acid 0.7%, 0.232. Ammonium hydroxide 28%, 0.239.

| | |
|---|---|
| Boiling 1 per cent H₂SO₄ (not aerated) | 0.34 (see *as*). |
| Boiling 0.7 per cent HNO₃ (not aerated) | 2.0 |
| Boiling 0.3 per cent HCl (not aerated) | 0.314 |
| 1 per cent HCl, room temperature (unagitated, not aerated) | 0.046 |
| 20 per cent HCl, 80° C. (unagitated, not aerated) | 25.0 |
| Boiling 1 per cent acetic (not aerated) | 0.21 |
| Boiling 99 per cent acetic (not aerated) | 4.0—11.0 |
| Boiling 2.5 per cent NaOH (not aerated) | 0.0044 |
| Boiling 20 per cent NaOH (not aerated) | 0.0004 |

Thickness of scale after two weeks in current of air at following temperatures:

| | |
|---|---|
| 800° C. | 0.008 in. |
| 900° C. | 0.220 in. |

*aw* Nickel (commercially pure): Losses in inches thickness per mo. × 10² (room temperature): Sulphuric acid 10%, 0.026. Hydrochloric acid 0.3%, 0.037; 20%, 0.08; concentrated 0.82—0.94. Acetic acid 1%, 0.016; 99%, 0.018—0.022. Anhydrous NH₃, 0.014. Sea water, 0.0007—0.0011. Same thing agitated but not aerated: Ammonium hydroxide 28%, 0.277.

*ay* In presence of ferric salts, rated as "Fair."

*aw* 5 per cent H₂SO₄ (unagitated, not aerated) 38—49° C. ... 0.141 (see *as*)
5 per cent HNO₃ (unagitated, not aerated) 38—49° C. ... 0.635
5 per cent acetic (unagitated, not aerated) 100° C. ... 0.197—0.214
Thickness of scale after two weeks in current of air, 0.001 in. at 800° C.

*bf* Davis Metal. Penetration in inches per mo. × 10² in solutions 140—150° F. with agitation at rate of 2.5 in. per min., except for Cl in aqueous solution (70° F., 0 velocity): Sulphuric acid 10%, 0.035; 30%, 0.027. Hydrochloric acid 10%, 0.91. Ammonium hydroxide, 10%, 0.081. Chlorine solution, 0.44.

*bi* Everdur. Penetration per mo. at 25° C. unagitated: Sulphuric acid 20%, 0.011; 70%, 0.004. Hydrochloric acid 20%, 0.023; concentrated, 0.224. Sea water spray, 0.0028. Mine waters, 0.052 (velocity 8 ft. per sec.). Chlorine solution (12.5 g. per liter), 0.16.

*bk* Loss in mg. per sq.in. per day. (room temperature, unagitated): Annealed 825° C.: Sulphuric acid 2%, 0.18; 5%, 0.40.

*bm* Illium, unagitated, loss in mg. per sq.in. per mo. At 20—30° C.: Sulphuric acid 10%, 1.87; 25%, 1.03; 95%, 0.19. Nitric acid 10%, 0.19; 70%, 1.55. Hydrochloric acid 5%, 32.9; 25%, 244. Acetic acid 99%, 0. At 70—75° C.: Sulphuric acid 10%, 23.9; 25%, 49.7; 95%, 32.9. Nitric acid 10%, 11.6; 70%, 29.7. Hydrochloric acid 5%, 851; 10%, 1071. Acetic acid 99%, 3.87.

| | |
|---|---|
| *ca* Penetration in inches per month × 10² (room temp) | 0.04 to 0.05 |
| *cb* Penetration in inches per month × 10² (room temp) | 0.09 to 0.10 |
| *cc* Penetration in inches per month × 10² (room temp) | 0.08 to 0.30 |
| *cd* Penetration in inches per month × 10² (room temp) | 0.05 to 0.30 |
| *ce* Penetration in inches per month × 10² (room temp) | 5.0 to 6.0 |
| *cf* Penetration in inches per month × 10² (room temp) | 0.30 |

### Table I—Properties of Corrosion-Resistant, Heat-Resistant and Electrical-Resistance Alloys of General Manufacturing Interest

| Manufacturer | Designation of Material | Essential Nominal Chemical Composition, per cent | | | | | | | | | | Density, g. per cc. | Melting Point, deg. Cent. | Total-Contraction, in. per ft. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | C | Si | Mn | Ni | Cr | Fe | Cu | Zn | Sn | Al | | | |
| Allegheny Steel Co..... | Ascoloy............ | | | | | 14.0 | a | | | | | 7.65 | 1493j | ........ |
| | Carp. Stainless......... | 0.30 | ....... | | | 14.0 | a | | | | | 7.7 | 1430k | ........ |
| Carpenter Steel Co..... | Carp. Rustless........ | 0.30 | ....... | | | 20.0 | a | 1.0 | | | | 7.7 | 1430k | ........ |
| | 30-per-cent Nickel Steel | | | | 30.0 | | 69.0 | | | | | 8.02 | ........ | ........ |
| | Corrosion Resistant Steel. | 0.45 | ....... | | | 9.5 | a | | | | | | ........ | ........ |
| | No. 2600 Metals........ | From | From | | From | From | From | | | | | 7.76 | 1480k | *l* |
| Crucible Steel Co..... | Resistal No. 4f......... | 0.15 | 1.25 | | 22.0 | 5.5 | 65.0 | | | | | 7.76 | 1480k | *l* |
| | Resistal No. 7g........ | to | to | | to | to | to | | | | | 7.76 | 1480k | *l* |
| | Resistal No. 8h........ | 0.70 | 3.25 | | 36.0 | 27.5 | 45.0 | | | | | 7.76 | 1480k | *l* |
| Cyclops Steel Co...... | No. 17 Metal........ | 0.45 | 1.00 | 0.75 | 20.0 | 7.5 | a | | | | | 8.00 | ........ | *hi* |
| Firth-Sterling Steel Co. | S-less Stainless Steel.... | 0.30 | | | | 13.0 | a | | | | | 7.75 | 1510k | .... |
| | S-less Stainless Iron..... | 0.15 | | | | 13.0 | a | | | | | | ........ | .... |
| | Delhi Tough Iron....... | 0.07 | 1.25 | | | 17.0 | a | | | | | 7.62 | 1510 | .... |
| Ludlum Steel Co...... | Delhi Hard.......... | 1.20 | 1.50 | | | 17.0 | a | | | | | 7.63 | 1510 | .... |
| | Silcrome........... | 0.40 | 3.50 | | | 8.25 | a | | | | | 7.60 | 1510 | .... |
| | Silcrome, Grade F..... | 0.40 | 3.30 | | | 3.25 | a | | | | | 7.66 | 1510 | .... |
| | Stainless Steel (Low C). | 0.35 | 0.35 | 0.50 | | 15.0 | a | | | | | | ........ | .... |
| The Midvale Co....... | Stainless Steel (Med. C).. | 0.80 | 0.35 | 0.50 | | 18.0 | a | | | | | | ........ | .... |
| | Stainless Steel (High C).. | 1.00 | 0.35 | 0.50 | | 23.0 | a | | | | | | ........ | .... |
| Vanadium Alloys Steel Co | Stainless Steel......... | 0.33 | | | | 14.0 | a | | | | | | ........ | .... |
| The Coloriaing Co..... | Calite A............ | 0.80 | | | 35.0 | 15.0 | a | | | | | 7.8 | 1480 | *i* |
| | Calite B............ | 1.50 | | | 6.0 | 18.0 | a | | | | | 7.8 | 1480 | *i* |
| Carobaltic Tool Co..... | Fire Armor.......... | | | | 61.0 | 18.5 | a | | | | | 8.0 | 1440 | *i* |
| Michigan Steel Casting Co............... | Misco Metal........... | 0.50 | 1.50 | 0.50 | 25.0 | 15.0 | 57.5 | | | | | 7.65 | ........ | *p* |
| | Nichrome........... | | | | 60.0 | 12.0 | a | | | | | 8.15 | 1300 | .... |
| | Nichrome........... | | | | 66.0 | 16.0 | a | | | | | 8.06ac | 1260 | *i* |
| | Nichrome III......... | | | | 85.0 | 15.0 | | | | | | 8.5 | 1320k | .... |
| | Nichrome IV.......... | | | | 80.0 | 20.0 | | | | | | 8.5 | ........ | .... |
| Driver-Harris Co...... | No. 193 Alloy......... | | | | 30.0 | 2.0 | a | | | | | 8.15 | ........ | .... |
| | Cimet............. | | | | 25.0 | | a | | | | | | *l* | .... |
| | Cimet............. | | | | 25.0 | | a | | | | | 7.60 | *l* | *¹⁄₁₆* |
| | Advance............ | | | | 45.0 | | | 55.0 | | | | 8.9 | ........ | .... |
| | Manganin........... | | | 12.0 | 4.0 | | | 84.0 | | | | 8.15 | ........ | .... |
| Cutler Steel Co. and Driver-Harris Co., licensees of Electro-Metallurgical Co..... | Chrome Iron, Duraloy, Cimet............. | | | | | 20.0h | a | | | | | 7.6–7.8 | 1150–1450 | *i* |
| Haynes Stellite Co...... | Stellite............. | | | | | x | | | | | | 8.2–9.3 | 1230 min. | *i–¹⁄₁₆* |
| The Duriron Co........ | Duriron............ | 0.60 | 14.25 | 0.35 | | | 84.6 | P0.16 | | S0.04 | | 7.00 | 1250 | *¹⁄₁₆* |
| Pacific Foundry Co.... Bethlehem Foundry and Machine Co..... | Corrosion ......... | | 13.5 | | | | 85.5 | | | | | 7.00 | 1290–1330 | ........ |
| | Karma............. | | | | 80.0 | 20.0 | | | | | | 8.4 | 1415 | .... |
| | Elaleo Rayo......... | | | | 85.0 | 15.0 | | | | | | 8.43 | 1410 | .... |
| | Elaleo Calido........ | | | | 60.0 | 16.0 | a | | | | | 8.15 | 1400 | .... |
| | Elaleo Comet........ | | | | 30.0 | 5.0 | a | | | | | 8.3 | 1480 | .... |
| Electrical Alloy Co.... | Elaleo Pure Nickel..... | | | | 98.0+ | | | | | | | 8.84 | 1450 | .... |
| | Elaleo Manganese Nickel. | | | 2.0 | 97.0 | | | | | | | 8.84 | 1430 | .... |
| | Elaleo Mango........ | | | 5.0 | 95.0 | | | | | | | 8.8 | 1420 | .... |
| | Elaleo Ideal......... | | | | 45.0 | | | 55.0 | | | | 8.9 | 1210 | .... |
| | Chromel A.......... | | | | 80.0 | 20.0 | | | | | | 8.40 | 1430k | .... |
| | Chromel B.......... | | | | 85.0 | 15.0 | | | | | | 8.40 | 1400k | .... |
| | Chromel C.......... | | | | a | 11.0 | 25.0 | | | | | 8.26 | 1430k | .... |
| Hoskins Manufacturing Co. | Chomel D.......... | | | | 26.0 | 8.0 | 66.0 | | | | | 8.26 | ........ | .... |
| | Chromel Alloy No. 502.. | | | | 25.0 | 20.0 | 55.0 | | | | | 8.26 | 1430k | *¹⁄₃₂* |
| | Copel............. | | | | 45.0 | | | 55.0 | | | | 8.87 | ........ | .... |
| | Alloy No. 484........ | | | 1.5 | a | | | | | | | | ........ | .... |
| | Monel Metal........ | C+Si | 1.0 | 2.0 | 67.0 | | | 2.0 | 28.0 | | | 8.80 | 1300–1350 | *i* |
| International Nickel Co | Nickel (Commercially Pure)........... | | | 0.25–5.0 | 94–99 | | | | | | | 8.84 | 1450 | *i* |
| American Metal Products Co......... | Ampeo ........... | | | | | | 8.0 | 82.0 | | | 10.0 | 7.71 | 995 | *i* |
| Aterite Co., Inc........ | Aterite............ | | | | 10.0 | | 2.0 | 65.0 | 23.0 | | | 8.57 | 1305 | .... |
| | Aterite............ | | | | 35.0–44.0 | | 5.0 20.0 | 55.0–36.0 | 5.0– | | | 8.46 | 1540 | .... |
| Chapman Valve Manufacturing Co........ | Davis Metal......... | C+Si | 0.5 | 1.5 | 29.0 | | 2.0 | 67.0 | | | | 8.75 | 1340 | .... |
| | Naval Brass......... | | | | | | | 61.0 | 38.0 | 1.0 | | 8.40 | 885 | .... |
| | Admiralty Tubing...... | | | | | | | 70.0 | 29.0 | 1.0 | | 8.54 | 935 | .... |
| Chase Metal Works.... | Commercial Bronze Rod.. | | | | | | Pb0.75 | 86.0 | 12.75 | 0.5 | | 8.75 | 1000 | .... |
| | 18-per-cent Nickel Silver. | | | | 18.0 | | | 66.0 | 16.0 | | | 8.75 | 1110 | .... |
| Curtis Bay Copper and Iron Works........ | Everbrite No. 90....... | | | | 35.0 | | | 60.0 | | | | | ........ | .... |
| | Everbrite No. 92....... | | | | 35.0 | | | 58.0 | | | | | ........ | .... |
| Dupont Engineering Co | Everdur No. 50 Metal... | | 4.5 | 1.0 | | | | 94.5 | | | | 8.45 | 1050 | .... |
| | | | | | | | | | | | | 8.15 | | *¹⁄₁₆–¹⁄₈ am* |
| Frontier Bronze Corp.. | Titanium-Aluminum Bronze No. 1...... | | | | | | | 90.0 | | | 10.0 | 7.45 | 980 | *i* |
| | Titanium-Aluminum Bronze No. 5...... | | | | | | 1.0 | 89.0 | | | 10.0 | 7.45 | 980 | *i* |
| | Naval Brass......... | | | | | | | 60.0 | 39.25 | 0.75 | | | ........ | .... |
| Scovill Manufacturing Co........ | Admiralty Metal....... | | | | | | | 70.0 | 29.0 | 1.0 | | | ........ | .... |
| | Admiralty Nickel...... | | | | 29.0 | | | 70.0 | | 1.0 | | | ........ | .... |
| | Spring Oreide........ | | | | | | | 92.0 | | | 8.0 | | ........ | .... |
| Standard Calorimeter Co.. | Illium............. | | 0.5 | 1.5 | 63.0 | 21.0 | | 8.0 | Mo.4.0 | W.2.0 | | 18.3 | 1.300 | *¹⁄₁₆* |

**NOTES**

*a* Balance (including accidental impurities).
*b* Acetylene satisfactory.
*c* Erichsen Values (annealed).
    ¹⁄₁₆ in. Sheet............. 6 to 7
    ¹⁄₁₀ in. Sheet............. 8 to 9
    ¹⁄₈ in. Sheet............. 8 to 10
*d* Also cold rolled, tempered and tempered-and-polished strip.
*e* Lowest in alloying elements.
*f* Intermediate between 7 and 8.
*g* Highest in chromium.
*h* Highest in nickel.
*i* Data applies to bars only.
*j* ±15° C.
*k* Approximate.
*l* About as for cast iron.
*m* Recommend 50 Cu–50 Zn and flux of Borax. FeCl₂, HCl, ZnCl₂ at 870° C.
*n* Cold work increases corrodibility.
*o* Use calite "A" molding rod.

*p*¹⁄₈ in. in green sand molds.
    ¹⁄₁₆ in. in dry sand molds.
*q* Data applies to castings only.
*r* Data applies to sheet only.
*s* Also used for abrasion resistance.
*t* Varies widely according to composition.
*u* Minimum, usually 25–30 per cent.
*v* Properties apply to rolled products.
*w* Possible, but not as satisfactory as acetylene.
*x* Series of Co-Cr-W alloys.
*y* O.K. with acetylene if excess of gas is used.
*z* Use duriron welding rod and great care in pre-heating and cooling.
*ab* Preheat entire casting thoroughly and cool slowly after welding. Use rod of same material.
*ac* Value is for castings; for forged material, density is 8.15.
*ad* Balance.
*ae* Total insolubles.
*af* Use borax as flux.
*ag* Rolling temperature.
*ah* In all welding, use flux of borax or fluorspar

or fluorspar and iron oxide. Weld quickly to avoid boiling and consequent unsoundness.
*ai* Not embrittled by brazing.
*aj* Works practice; may be reduced 95 per cent. Erichsen on annealed sheet:
    0.020-in. sheet...............12.7
    0.125-in. sheet...............15.2
*ak* Same as *aj*, but Erichsen slightly higher.
*al* Requires, for soldering, use of special metal and flux.
*am* According to thickness of section.
*an* Use ¼ spelter solder and ¾ borax.
*ao* Milling not recommended.
*ap* Erichsen values:
    0.008-in. sheet, hard.........2.3 to 2.9
    0.012-in. sheet, hard.........2.9
    0.020-in. sheet, hard.........3.8
    0.012-in. sheet, soft.........5.2
    0.020-in. sheet, soft.........5.6
    0.010-in. sheet, annealed.........8.5
*aq* Erichsen value, 0.0045-in. sheet, 8-in. hard, 0.9 to 1.2.

| Manufacturer | Designation of Material | Miscellaneous Corrosion Data |
|---|---|---|
| Allegheny Steel Co........ | Ascoloy.................. | Resistant to molten Sn, Pb, type metal; also immune to attack of many organic acids, solutions of many carbonates, nitrates and sulphates, $CH_3Cl$, $ZnCl_2$; not good for molten Zn or $MnNO_3$ or for acetic acid at 90°C.; no loss at 800° C. (50-hr. test, atmosphere not stated). |
| Carpenter Steel Co....... | Carp. Stainless........... | Resistance to saturated or superheated steam, excellent. |
| | Carp. Rustless............ | Good in molten brass and other non-ferrous metals. |
| | 30 per-cent nickel steel..... | Not recommended for use with acids. Does not pit and is easily cleaned. Much better in corroding media |
| | Corrosion-resistant steel.... | than carbon steel. |
| Crucible Steel Co......... | No. 2600 metal........... | 21 hr. room temperature, chrome alum fixing bath, 4.7 mg. per sq.in.; 4 hr. 0.001 $HgCl_2$, room temperature, 2.7 mg. per sq.in.; 85 per cent $H_3PO_4$, 90° C., 6 hr., 140 mg. per sq.in. |
| | Rezistal No. 4............ | |
| | Rezistal No. 7............ | 21 hr. room temperature, chrome alum fixing bath, no loss; 15 per cent lactic acid 24 hr. or 30 per cent lactic |
| | Rezistal No. 8............ | acid 7 hr., 90-100° C., no loss; 0.001 $HgCl_2$ 4 hr. room temperature, no loss; 85 per cent $H_3PO_4$, 2 hr., 90-100° C., 1.3 mg. per sq.in. |
| Cyclops Steel Co......... | No. 17 metal............ | Sulphates and chlorides generally attack this steel. |
| Firth-Sterling Steel Co..... | S-less Stainless steel....... | |
| | S-less Stainless iron....... | |
| Ludlum Steel Co.......... | Delhi Tough Iron........ | O. K. in lead at 1000° C. Excellent for nitric or acetic acid at boiling point. No weight loss due to scaling up to 1000° C. |
| | Delhi Hard............. | Good in nitric or acetic acid at boiling point. No weight loss due to scaling up to 930° C. |
| | Silcrome.............. | O. K. in lead at 950° C. Excellent for nitric or acetic acid at boiling point. No weight loss due to scaling up to 950° C. |
| | Silcrome, grade F........ | Not immune to corrosive influences, but initial oxide coating protects metal against progressive corrosion, poor in acids. No weight loss due to scaling up to 930°C. |
| The Midvale Co.......... | Stainless Steel (Low C).... | Excellent for steam service. |
| | Stainless Steel (Med. C)... | Excellent for steam service. |
| | Stainless Steel (H.gh C)... | Excellent for steam service. |
| Vanadium Alloys Steel Co. | Stainless Steel........... | |
| The Calorizing Co........ | Calite A................ | Good in molten lead and molten salt baths (except cyanide). No reaction with carbonizing compounds |
| | Calite B................ | or cool distillates. |
| Chrobaltic Tool Co....... | Fire Armor............. | |
| Michigan Steel Casting Co. | Misco Metal............ | Loss in weight, 500 hr. at 1750° F. (atmosphere not stated), 14 per cent. |
| | Nichrome............. | Deteriorated by hot sulphur-bearing gases. O. K. in lactic acid. O. K. in molten tin and silver. Not good |
| | Nichrome............. | in sodium compounds at elevated temperature, particularly in carbonizing compounds containing $Na_2CO_3$; $BaCO_3$ less destructive. |
| Driver-Harris Co.......... | Nichrome III............ | Oxide is thin, quite impervious and adherent and so prevents further oxidation; does not flake on repeated heating and cooling. |
| | Nichrome IV............ | Alternate heating and cooling does not cause growth of metal. |
| | No. 193 Alloy............ | |
| | Cimet................. | Resistant to fruit acids and to sulphur-bearing gases at elevated temperatures. |
| | Cimet................. | |
| | Advance................ | |
| | Manganin............. | |
| Cutler Steel Co. and Driver-Harris Co., licensees of Electro-Metallurgical Co. | Chrome Iron, Duraloy, Cimet................ | Excellent in phosphoric, citric and other fruit acids. Excellent resistance to molten Ag; good resistance to molten brass, salt and niter baths. |
| Haynes Stellite Co......... | Stellite................ | Excellent in iodine, 10 per cent trichloracetic acid. Good in 1/500 $HgCl_2$, conc. HF, fair in 6 per cent $H_2SO_3$.[a] |
| Duriron Co............... | Duriron............... | Excellent for arsenic salts, sulphates, chlorides, nitrates, phosphates and organic acids. Not good for fused alkalis, Br, HF or chlorides of S. |
| Pacific Foundry Co....... Bethlehem Foundry & Machine Co............ | Corrosiron............... | Resists most corrosives extremely well. |
| Hoskins Mfg. Co.......... | Chromel A ............ | |
| | Chromel B............. | |
| | Chromel C............. | Excellent for molten lead and white metals and fairly resistant to cyanide and other molten salts. Suitable |
| | Chromel D............. | as stirrers for molten brass and aluminum, but not as containers for these metals |
| | Chromel Alloy No. 502.... | |
| | Copel................. | |
| | Alloy No. 484............ | |
| International Nickel Co.... | Monel Metal............ | Under 800° C., resists action of caustic alkalis, carbonates, cyanides, chlorides, etc., but not resistant to action of Al, Sn, Zn, Pb, etc. |
| | Nickel (commercially pure) | Resists action of caustic alkalis, carbonates, cyanides, chlorides, etc. Not recommended for use with molten metals. |
| American Metal Products Co................ | Ampco................. | Recommended for many chlorides, sulphates and salts of organic acids, also many of these acids, not for oxidizing acids or mixtures or $H_3PO_4$. |
| Aterite Co., Inc.......... | Aterite............... | Cast is similar to wrought Aterite; also good in superheated steam up to 675° C. |
| Chapman Valve Mfg. Co... | Davis Metal............. | No attack by formic, oxalic, citric, tannic, boric or common fatty acids at 150° F., nor by fuel oil, dry Cl or many organic volatile solvents at normal temperature. |
| Dupont Engineering Co.... | Everdur No. 50 Metal..... | No permanent expansion or growth on heating between room temperature and 1000° F. |

# Modern Ideas on Corrosion Resistance

*Views of Leading Metallurgists on Some Phases of This Vast Subject Were Presented at the Atlantic City Meeting of the American Society for Testing Materials*

A SYMPOSIUM extending through two sessions of the annual meeting of the A.S.T.M. at Atlantic City had for its subject corrosion-resistant, heat-resistant and electrical-resistance alloys. Papers were presented describing these metals, their properties and methods of determining them, followed by informal discussions on corrosion resistance in general and that of the various alloys in particular.

Appropriately enough, the symposium was opened by the presentation of a set of tables containing in the greatest possible detail the important properties of a large number of resistant alloys. It was the unanimous opinion of the meeting that such a wealth of this type of information has never before been collectively available. That part of the collection that is of particular value to the chemical engineer has been reproduced

from the tables presented and is to be found elsewhere in this issue.

P. A. E. Armstrong, vice-president of the Ludlum Steel Co., read the first technical paper of the session, an imposing document on corrosion-resistant alloys of the past, present and future. The historical portion of the paper contained a remarkably complete review of the patents that have been granted in this field, for, as Armstrong points out, a patent is a technical article. Other technical articles and a description of the effects of various alloying elements brought the story of these metals up to the present day, and from that point the author ventured somewhat into the field of prediction. He has the greatest of confidence in the future of the rustless irons, which he believes will become standardized with a chromium content of about

17 per cent (most of them at the present time have 12 to 14 per cent Cr) and an added element. This element may be silicon, nickel, molybdenum or some other.

Dr. B. D. Saklatwalla later in the session commented on Mr. Armstrong's paper, calling attention to points that he felt should be mentioned if rustless iron were under discussion. He states that for wide use of these metals a low price is necessary and mentioned the method by which rustless irons can be produced directly from chrome ore, reducing it with silicon. The basic patent on this process, he says, is 10 years old and the metal produced is equally as clean as that produced by the usual methods. Dr. Saklatwalla believes copper to be the most useful element to use in conjunction with chromium to produce corrosion resistance.

Corrosion-resisting alloys for use in acid mine waters have been studied by Robert J. Anderson and George M. Enos, and a report of the results was presented in great detail. It was found from one set of tests that a high-chromium steel, two chromium-nickel-silicon steels, a high-silicon cast iron and a nickel-chromium-iron alloy were quite resistant, while metals differing in composition only slightly from these failed to stand up against the waters encountered in the coal-mining industry. Anderson and Enos described an accelerated electrolytic corrosion test at a later session. W. G. Whitman, of M.I.T., pointed out some features of their results that would seem to indicate that the test is not a reliable one. He showed that it came nearer checking Faraday's law than it did the long-time corrodibility test of some of the metals investigated. This statement was met by another speaker, who believed that the accelerated electrolytic corrosion test would be of real value and reliability when more is known of the present disturbing factors.

Dr. D. J. McAdam, Jr., metallurgist of the Naval Experiment Station at Annapolis and an eminent authority on metal endurance testing, contributed a comprehensive study of the endurance properties of corrosion-resistant steels. This scholarly presentation, replete with highly technical detail, indicated that the endurance properties of the corrosion-resistant steels are similar to those of other alloy steels, settling a point of great importance to the designer of machines subject to the attack of corrosive gases or liquids.

Two papers by European engineers were offered at this session, one by B. Strauss, of the research staff of Krupp's, Germany, and the other by Axel Hultgren, of the Gothenburg laboratory of Aktiebologet Svenska Kullagerfabriken.

The first, read by Dr. P. D. Merica, describes the development of non-rusting chromium-nickel steels. Strauss was the pioneer in this development and the metals described were the first rustproof steels publicly advertised as such. One of these steels, designated "V2A," is well adapted for a great variety of uses in the chemical industries, where it is called upon to resist the attack of nitric acid, ammonia or hydrogen peroxide in the presence of steam (aqueous vapors). Its resistance to hot dilute sulphuric acid is not satisfactory, but if a small percentage of nitric acid be added to the solution, "V2A" steel becomes absolutely passive and is no longer attacked by the acid. "V2A" lends itself well to electric and autogenous welding, and can thus be readiliy fabricated into apparatus for chemical uses.

Hultgren's paper, presented by Dr. Haakon Styri, described an investigation of stainless steel for ball bearings. The results indicated that it is unsuitable for this purpose. In commenting on this paper later Jerome Strauss said that the heat-treatment used at the time of Hultgren's tests are known now to have been productive of results inferior to those obtained by recently developed treatments in which higher temperatures are used and better results achieved; from which it may be hoped that stainless steel may in the future be adapted to the manufacture of completely corrosion-proof ball bearings. At present they can be used for this purpose, but they require the protection of grease.

In a paper prepared by himself and J. W. Talley, also of the U. S. Naval Gun Factory, Washington, D. C., Jerome Strauss provided a great quantity of information on stainless steels, their heat-treatment and resistance to seawater corrosion. The possibilities of these steels have been thoroughly probed and the effect of heat-treatment on the physical and chemical properties studied. For structural applications where a thin film of rust that does not penetrate far beyond the visible surface is acceptable or where frequent cleaning is possible, it was found that any of the "unhardenable" chromium steels may be satisfactorily employed. For the best results, steels with chromium under 15 per cent (or perhaps 14 per cent) must be heat-treated prior to use if the carbon content aproaches 0.20 per cent. In cases where attention is not possible or convenient and a permanently bright surface is desired, only one of the steels studied offered promise, and perfect behavior cannot be expected in every case. The proportional limit of all of the steels is low, but may be modified to some degree by thermal treatment; it varies from approximately 10 per cent or less to 50 per cent of the tensile strength. In spite of their ductility, these steels, with a few exceptions, have generally low impact strength.

The discussion following the first session included a description of "Admiralty Nickel," recently developed by W. B. Price, of the Scovill Manufacturing Co. It contains 70 per cent Cu, 29 per cent Ni and 1 per cent Sn; can be hot or cold worked and has high corrosion and heat resistance. Detailed information regarding its behavior under specific conditions is not yet available.

## HEAT-RESISTANT ALLOYS

F. A. Fahrenwald, a well-known consulting engineer of Cleveland, described at length his ideas on metals for use at high temperatures, taking into consideration physical strength, thermal expansion, specific heat and heat content, heat transfer, chemical stability and the co-ordination of all of these factors in designing equipment to work at high temperatures continuously or intermittently.

The alloys that resist the weakening effect of high temperatures and the chemical action of gases at these temperatures are usually of the solid solution type consisting of one of the metals of the iron group with aluminum, chromium, zirconium or some such metal which provides a tight protective oxide coating under oxidizing conditions. There are then only a few metals available, hence the possibilities seem to be limited. The ternary alloys have been found to give the greatest strength, variation of choice of constituent elements providing variation of other physical properties. The strains due to thermal expansion become of the greatest importance where temperature changes of large magnitude are encountered, so that a low coefficient of expan-

sion combined with high strength and ductility is a goal to be aimed at.

Only a few of the high points of Fahrenwald's discussion can be touched upon here, though the complete paper is of great interest to the worker who has high-temperature problems. The hardness provided by overstrain or heat-treatment is of no value, of course, in this work, and the stable "hardness of constitution" of alloys having no critical points must be depended upon. These metals have no obvious yield point at high temperatures, but are subject to "viscous flow," the viscosity decreasing as the temperature rises. Fahrenwald describes the change in properties as passing through those of copper, lead, tin and mercury successively. If the viscosity is great enough at a given temperature and below the "permissible sustained load stress," the deformation will not be objectionable. The determination of the safe load stress is difficult, however. The change of temperature repeatedly between high and room temperature often causes failure. **Mr.** Fahrenwald asks whether this is due to fatigue.

A study of particular interest to the chemical engineer was described by J. S. Vanick, formerly of the Fixed Nitrogen Research Laboratory, on the deterioration of some metals in hot reducing ammonia gases. Reducing gas mixtures of ammonia in nitrogen and hydrogen produce an intergranular fissuring in commercially pure iron, nickel, copper and some of their alloys. Exposures of samples in the form of corrosion specimens, tension test specimens or pressure bombs were made for as long as 6 months, to a synthesizing ammonia-gas mixture at a temperature of 500 deg. C. and a pressure of 100 atmospheres. Short exposures were made to decomposing or "cracking" ammonia.

## METALS USED IN NITROGEN FIXATION

None of the metals except those exposed to "cracking" ammonia was corroded in the sense in which corrosion is usually understood—namely, as a surface attack accompanied by disintegration or the formation of chemical compounds. With corrosion so defined, nearly all of the materials tested resisted corrosion successfully with some advantage in favor of the non-ferrous or non-ferrous alloy groups. Nearly all of the materials suffered a deterioration as measured by loss in mechanical properties such as tensile strength and ductility. For resistance to deterioration in a service requiring ability to sustain stress, as in heated bombs holding the gas mixtures under pressure, iron-base alloys of the type containing nickel, chromium or aluminum seemed to offer most resistance.

In the synthesizing ammonia-gas mixture, most of the metals are subject to integranular fissuring and voiding. (In the discussion it was asked what was left in the spaces between the crystals of the metal where this occurred, to which Mr. Vanick replied that the spaces were apparently left actually void.) This form of deterioration varies in rate and degree for the different materials. An intensification of the characteristic type of deterioration occurs in the catalyst zones during either "cracking" or synthesizing. Copper and Monel rods exposed to cracking ammonia show evidence of a vigorous attack culminating in their disintegration. The influence of the direction of the reaction with respect to ammonia equilibrium—that is, whether synthesizing or cracking ammonia is active—is shown in the rate at which deterioration occurs, being more rapid in the cracking gas.

In the cracking gas, nitrides form which, with the removal of impurities and the accompanying large evolution of hydrogen, account for the disintegration and deterioration of affected metals. In the synthesizing gas, nitrides are unstable and consequently are not expected to contribute directly to the deterioration.

An explanation to account for the deterioration in the synthesizing mixtures is developed as follows:

1. The removal of elements such as carbon or oxygen or their compounds encourages voiding and fissuring, while the presence of chromium in forming more stable nitrides and retarding the diffusion and penetration of the gas assists in resisting deterioration.

2. Fissuring induced by dissolved hydrogen made soluble by activation from infiltration through the metal or by release from ammonia which is rendered unstable in contact with the catalytic metal surfaces.

3. The more rapid diffusion and effusion of hydrogen in contrast to other gases of the mixture, permitting an ammonia enrichment to the extent of developing a localized super-equilibrium with the alternate formation and decomposition of nitrides, as a result.

## APPLICATIONS OF CHROMIUM ALLOYS

C. E. MacQuigg of the Union Carbide & Carbon Research Laboratories of Long Island City, who has in the past year or two presented in several papers the most complete information on record regarding high-chromium alloys for heat and corrosion resistance, described some engineering application of these metals. It would be futile to try to cover even sketchily the information covered in the paper. It is apparent that great possibilities exist for the utilization of alloys of the general type discussed, for low-temperature carbonization of fuel, recuperator design, and, in general, all forms of apparatus in which a high thermal conductivity and a high tensile strength can advantageously be combined with the oxidation resistance of a refractory. These three requirements, when successfully met, certainly do much to improve the thermal efficiency of chemical processes and thus conserve fuel.

A report on this corrosion symposium would not seem complete without reference to a paper presented at a later session on tests of the corrodibility of metals. There has been a lack of collected information on this subject which is admirably filled by this work of Henry S. Rawdon and A. I. Krinitsky, of the Bureau of Standards, and W. H. Finkeldey, of the New Jersey Zinc Co. The different forms of apparatus described and illustrated by slides covered the following types of tests: Simple immersion, electrolytic, continuous repeated immersion, interrupted repeated immersion, mist or spray and a simulated atmospheric test.

Information is not available that will permit definite conclusions as to which is the best "all around" method, if, indeed, the corrodibility of a metal under any and all kinds of service conditions can be measured by one single test. F. N. Speller, of the National Tube Co., advanced it as his opinion that it cannot, and this opinion found almost general agreement among the engineers present.

It was stated by several that "the tests should be tested" by comparison with long-time practical tests, but the great value of the tests as they are was generally appreciated. Where corrosion is to be studied in a laboratory, advantage may be taken of the experience of and the data collected by the authors of the paper, and they freely offer their co-operation.

# News of the Industry

## Summary of the Week

Use of poison gas as a means of boll weevil control to be studied at Tallulah, La.

Engineering educators stress research plans at Colorado meeting.

Use of chlorine as a cold cure continues to prove effective.

Report on tariff investigation into cost of producing linseed oil is not expected until late in September.

Effort to be made to build up efficiency of Patent Office.

Carnegie Steel Co. completes construction of world's largest coke plant.

World survey of naval stores situation will be undertaken by Department of Commerce to promote sales.

Treasury Department is planning important changes in current invoice forms and consular certificates.

### Poison Gas as Insecticide Studied by C.W.S.

Field work will be conducted at Tallulah, La., and at a Georgia point by the Chemical Warfare Service, in connection with its experiments to determine the efficacy of poison gas as a means of boll weevil control. Tallulah, La., has been chosen because the Department of Agriculture maintains a large laboratory there. It is desired, however, to conduct experiments with gas at another point where conditions are radically different from those in the vicinity of Tallulah.

Exhaustive tests will be made in the use of cyanogen chloride and with a radically different gas, the nature of which is not being announced at this time.

So far as past experimentation has revealed, cyanogen chloride seems admirably adapted to this work. It is so much heavier than air that it clings closely to the ground. Its potentiality as a tear gas gives ample warning of its presence. The plan is to release the gas on a quiet evening and allow it to move slowly through the stand.

In connection with the work on boll weevil control, similar experiments will be conducted in the application of poison gas in the control of sugar cane pests.

### World Survey to Promote Buying of Naval Stores

A world survey of the naval stores situation is to be undertaken by the Chemical Division of the Department of Commerce. The matter will be approached from the trade promotion angle.

Domestic producers of naval stores are urging curtailment of production to meet the situation being aggravated by continued decline in the foreign trade.

The Department of Commerce does not regard curtailment of production as being justified in most instances.

### *State Department Enters Into Nitrate of Soda Case*

The State Department has under consideration the recent action in Chile which affects the interests of the American companies engaged in the production of nitrate of soda. The department will make no statement as to the scope of the investigation, but it is expected to be a comprehensive one.

Instead of curtailing production, renewed efforts should be made to sell the product. As viewed by the department's chemical specialists, there is no reason why foreign demand should be slackening. At present the domestic industry is doing nothing to stimulate foreign buying. The belief is expressed that systematic trade promotion would stimulate foreign buying to the point where no curtailment of the present rate of production is necessary.

### Patent Office Reorganization to Be Attempted

Secretary of the Interior Work has recently taken steps to formulate a committee composed of representatives of the American Bar Association and leading patent bar associations of the country to simplify methods of procedure and expedite the business of the Patent Office.

The plan of Secretary Work is to have the committee after its organization make a thorough review of the Patent Office and to submit suggestions for changes in methods that should result in bringing the work of the bureau to a current basis in the near future. Because of a tremendous increase in the patent business during the last few years the Patent Office has been unable to keep up with the number of applications for patents that have been filed by the public.

### Carnegie Completes World's Largest Byproduct Coke Plant

The Carnegie Steel Co. has just completed what is said to be the largest byproduct coke plant in the world, at its Clairton, Pa., works. It has been in course of construction for about 2 years, and supplements the original byproduct coke plant at this place. The new plant consists of 366 ovens, arranged in six batteries of 61 ovens each. It has a daily capacity for the carbonizing of 8,500 tons of coal, producing in this period a total of 6,000 tons of coke, 55,000,000 cu.ft. of gas, 90,000 gal. of tar, 215,000 lb. of ammonium sulphate and 25,000 gal. of benzol products. It is proposed to develop the new works to their maximum capacity as soon as the conditions warrant.

### Chlorine Treatment for Colds Proves Effective

An average of forty cases a day are being treated in the experimental chlorine chamber being operated by the Chemical Warfare Service. The fact that so many persons avail themselves of this opportunity to receive treatment for colds, during the season when colds are fewest, is held to indicate the need for more opportunities to secure the chlorine treatment. There are now literally thousands in Washington who are willing to testify as to the effectiveness of the gas in the treatment of colds. Those suffering with hay fever and asthma claim to have experienced improvement after having taken several treatments.

While no results that would justify conclusions have been obtained in connection with the experiments with mustard gas and lewisite for the treatment of tuberculosis and locomotor ataxia, enough encouragement has obtained to justify intensive continuation of this work.

# News in Brief

**Ciment Fondu Industry Grows —** Lafarge & Co. of Le Teil are to make use immediately of an increased capital in the erection of modern cement plants at Valdonne and Cette, on the Mediterranean in southern France. This company held the original patents on ciment fondu, or aluminous cement, the use of which is steadily increasing. As a part of its program of extension it is proposed to construct various plants for the production of this specialty both in France and abroad.

**Sinclair Opens New Refinery—**The Sinclair Refining Co., Houston, Tex., has commenced the production of gasoline at its new refinery unit at Sinco, near Houston. An initial battery of stills has been completed, and work is in progress on another battery of ten stills, expected to be ready for service in August. It is planned to develop maximum capacity at the refinery with the new equipment.

**Chillicothe, Ill., to Have Alcohol Plant —** The Chamber of Commerce, Chillicothe, Ill., is completing negotiations, it is reported, for the construction of an alcohol-distilling and commercial solvents plant at North Chillicothe, which with machinery and equipment is estimated to cost $1,000,000.

**Oils and Fats Journal Announced—** Announcement has just been made that a new publication, the *Journal of Oil and Fat Industries*, is about to appear. The American Oil Chemists Society is sponsoring the magazine. Herbert S. Bailey, of Savannah, Ga., is to be editor. It is stated that various phases of the manufacture and use of animal and vegetable oils and fats are to be treated.

**Another Newsprint Mill Started —** The first steps toward the construction of a new 100-ton-a-day newsprint mill by the E. B. Eddy Co., Hull, Que., which is to cost in the neighborhood of $2,000,000, have been taken. The new undertaking will include extensive additions and improvements to the company's Hull plant. The building that will contain the new newsprint machine is so designed that a second machine of the same capacity can be added. The present sulphite mill will be entirely renovated.

**Silver Research Transferred —** That portion of the research work on silver which was being conducted by E. I. Shaw, who recently resigned from his position with the Bureau of Mines, has been taken over by Dr. E. L. Mack. He will work as a Bureau of Mines employee at the Bureau of Standards in co-operation with Dr. H. W. Gillett. This in no way will interfere with that portion of the silver work being done at the Reno station of the bureau.

**Canadian Beet Sugar Plant Planned** —Plans are being matured for the erection of a beet sugar factory at a point in the Red River Valley near Winnipeg before autumn, and an investigation is being made as to the possibility of securing the planting of from 6,000 to 8,000 acres in the valley to sugar beets. Assurance of large acreage has already been secured, and it is expected that no difficulty will be found in getting a sufficient supply of the beets.

**Lime and Gypsum Dust Grows in Use—**A series of maps has been prepared by George S. Rice and Oliver Bowles, of the Bureau of Mines, showing all limestone and gypsum quarries in coal-producing areas. The great impetus which safety education has given stone dusting in coal mines has produced a market for the fine material that results from quarrying operations.

## Japan Increases Consumption of Coal-Tar Food Colors

The consumption of coal-tar food colors in Japan has increased 100 per cent during the past 2 years, the average monthly importation having increased from 700 lb. in 1922 to 1,650 lb. during the first 4 months of 1924. The increasing popularity of foreign style confectionery and fancy pastry in Japan is further stimulating the demand for food colors. Confectioners, bakers, manufacturers of carbonated waters and soft drinks are gradually requiring more and more synthetic coloring matter.

German coal-tar food colors were once preferred to the American products in Japan, for the reason that they were obtained for about one-third of the cost of American colors. Recently, however, a more strict enforcement of the Japanese pure food regulations has caused a number of firms to use American and English colors in preference to the inferior German makes which do not, in all respects, comply with the Japanese pure food regulations.

## Germany Develops Domestic Supply of Rosin

Before the war Germany imported 80 per cent of its rosin requirements from the United States. The war cut off this source of supply and the German Government turned its attention to the development of a domestic industry. Firms were founded for the purpose of producing rosin. The most important of these was reorganized in 1923 as a joint stock company, after acquiring the property of several smaller firms. During the war the German Government had placed at its disposal some of the forests in Russian and Polish territory occupied by German troops. After the war producers were restricted to German forests and many firms went out of existence, but the industry continued to live. It is reported that the annual domestic production is rising slowly and approximates 25,000 to 28,000 metric tons. According to German Government statistics, imports from the United States in 1922 amounted to 18,500 metric tons, and in 1923 to 25,300 tons.

The present price for the domestic product, as shown in a report from N. P. Davis, Consul at Berlin, is higher than that for the American, and it is admitted that its quality is not equal, although it is considered good enough for most purposes.

# Trade Notes

The Spanish export duty on olive oils, not including sulphur olive oil, remains, for the month of July, 10 pesetas per 100 kilos, according to a cablegram received on July 5 from Assistant Trade Commissioner J. G. Burke, Madrid.

A report from Syracuse states that the Semet-Solvay Co. would pay $102 a share for all outstanding 8 per cent preferred stock of the Kingston Pocahontas Coal Co. if delivered before August 1.

William Lunham, formerly a member of the firm of Lunham & Moore of New York, died last week at Milford, Pa.

The National Ultramarine Co. of Cincinnati, has appointed Jayne & Sidebottom, Inc., of New York, as its sole selling agent and distributor in the Eastern territory.

Reports have been received in the oil trade to the effect that the Royal Greenland Trade, the commercial monopoly which controls all the trade of Greenland, has announced its intention of reviving the whaling industry in Greenland waters on a considerable scale.

Last Tuesday the Treasury Department announced that a drawback had been allowed on raw or processed linseed oil, oil cake and oil meal manufactured by the Archer Daniels Midland Co., with the use of imported flaxseed.

## Certificate of Origin Required for Goods Shipped to Spain

In view of the fact that Spanish importers of American merchandise are continually having trouble on account of the lack of properly prepared certificates of origin which should accompany goods consigned to them, Assistant Trade Commissioner James G. Burke, Madrid, calls attention to the fact that United States manufacturers and shippers interested in the Spanish market will not only aid their representatives in Spain but, by establishing a reputation for carefulness, promote their own business if they will give more careful attention to the details of the preparation of the documents covering shipments direct to Spain from the United States or sent in transit through a third country.

He suggests that all shippers of merchandise to Spain should consult the Spanish consular authorities in the port of embarkation, in order that their certificates of origin may be made out in proper form and in the exact wording of the Spanish general customs tariff classification. Owing to the lack of technical knowledge in Spanish customs offices, conformity to the exact wording of the tariff classification is necessary, inasmuch as otherwise the customs authorities may give the articles the wrong classification and levy duties in excess of those that should apply.

### Engineering Educators Plan Intensive Research

The Society for the Promotion of Engineering Education held its thirty-second annual meeting at the University of Colorado, Boulder, Colo., June 25 to 28, inclusive. The attendance, 362, exceeded all former records. The 150 members present represented 70 colleges, 38 states, Canada and Hawaii. Doubtless the large registration was in part due to the attractiveness of Colorado for summer vacation programs.

Much interest centered in the report of Dr. Wickenden, chairman of the board that is administering the $108,000 fund created by the Carnegie Foundation for the study of engineering education. Plans have been made to establish the proper length of engineering curricula. The belief is growing that mere juggling with the details of the present 4-year courses can effect only minor improvements and that any great advance in engineering education will require longer curricula.

The co-operation has been secured of the great industrial organizations (through the Joint Industrial Conference Board) and of the great national engineering societies (through a joint council). These agencies will assist in making job analyses of the work of engineers in different occupations and of the numbers of engineering graduates required to meet the needs of the country.

The new officers of the society are: President, Dean A. A. Potter of Purdue; vice-presidents, Prof. R. S. King, Georgia Institute of Technology, and Dean G. B. Pegram, Columbia University. Members of the council for 3 years, Dean G. M. Butler, University of Arizona; Prof. H. Pender, University of Pennsylvania; Dean E. B. Norris, State College of Montana; Prof. W. E. Brooke, University of Minnesota; Assistant Dean H. H. Jordan, University of Illinois; Prof. W. H. Kenerson, Brown University, and Director W. E. Wickenden. The secretary, Dean F. L. Bishop of Pittsburgh, and the treasurer, W. O. Wiley, of New York, were re-elected.

The 1925 meeting will be at Union College, Schenectady, N. Y.

### Breithut Will Begin Trade Addresses at Boston

A series of addresses is to be made by Dr. F. E. Breithut on the chemical situation in several European countries. Dr. Breithut recently returned from Europe, where he has served the past year as a special trade commissioner of the Department of Commerce. His tour will start at Boston, July 21. His itinerary includes Providence, Worcester, New York, Philadelphia and Wilmington. He will remain several days in each city so as to be available to those who desire to consult him on individual matters pertaining to trade promotion.

The Department of Commerce has not determined finally whether or not to continue the work which Dr. Breithut has been doing. A number of names have been submitted to the department for its consideration in case it should be decided to send another chemical trade commissioner abroad.

# Washington News

### Appropriation to Be Asked for Oil Shale Plant

An appropriation of $90,000 will be asked of Congress next December by the Bureau of Mines, for the purpose of establishing a plant in the field for the extraction of oil from shale, on which for several years the bureau has been engaged in laboratory experimentation. The estimate for this appropriation was submitted to the budget bureau several weeks ago and has been approved by General Lord, director of the budget, and by President Coolidge. The appropriation is to cover the construction of the plant, the land necessary for the plant, and the securing, by purchase or otherwise, of the necessary shale or shale land.

### Pushing Anhydrite Study

Laboratory work on the utilization of anhydrite is now under full headway at the New Brunswick station of the Bureau of Mines. One of the problems on which work is being done is the determination of the value of anhydrite as a cement retarder. The almost invariable tendency in American gypsum mines to encounter larger and larger proportions of anhydrite as depth is attained has greatly increased the need for finding a use for the anhydrite which now is not being utilized in any way.

### Tariff Commission About Ready to Take Up Linseed Oil Case

As soon as the Tariff Commission completes its report on its sugar investigation, which is expected to be very soon, it will take up for consideration the results of its investigation into the difference of cost of production in linseed oil. Inasmuch as several of the commissioners expect to be out of the city during the greater part of August, however, it does not appear probable that the linseed oil report will reach the President until late in September.

The linseed oil case has been before the commission for more than a year in all of its stages. The investigation into this commodity was the result of an application filed by the Bureau of Raw Materials in behalf of paint and varnish manufacturers, a decrease in the duty being asked under the flexible provisions of the tariff act. At the same time the bureau filed applications for reduction in several other vegetable oils. The commission docketed linseed oil, but held up the other applications for some months until recently, when the investigations into cottonseed oil, peanut oil, soya bean oil and coconut oil were ordered. The field work in the linseed oil case was completed several months ago and a public hearing was held last winter. Consideration of the report has been delayed by the commission owing to the long time necessary to take up the sugar report.

While there is no indication of the commission's action in the linseed oil case, the figures that were presented at the public hearing as a result of the work of its staff indicate that a decrease in the duty on this commodity would not be unexpected.

### New Apparatus for Testing Fast Colors in Germany

A new apparatus for testing the resistance of colors has been constructed at Hanau, Germany, in the form of a mercury vapor lamp, according to a report from Consul-General Dument at Frankfort.

The fading of color being chiefly due to the influence of ultra violet rays, which are not numerous in the ordinary daylight at low altitudes, the lamp accelerates the process in emanating these rays in considerable quantities. The effect on textiles, for instance, of an hour's exposure to this source of light is greater than that of many hours' exposure to the ordinary sunlight.

The lamp has a quartz glass burner similar to those used for medicinal purposes and is said to be more powerful than any other model. Mercury vapor, which at high temperature emanates the desired chemically active rays, is contained in an air-tight, transparent tube of quartz glass and heated by electric current. Contrary to ordinary glass, the fused quartz allows the ultra violet rays to pass freely. It remains firm at a temperature at which glass liquefies. The apparatus consists of a quartz burner and a suspension and tilting mechanism, the latter used in igniting the lamp. It is possible to direct the rays in any direction. With alternating current, it is necessary to place the transformer on the floor on account of its weight.

Owing to the extraordinarily high temperature obtainable, large quantities of ultra violet rays emanate from the mercury vapor, making the lamp valuable for testing the resistance of colors. In the market it is known as the "Original Hanau" and designated as "a color testor by means of artificial, high altitude sunlight." In fusing quartz, iridium vessels must be used, much oxygen is consumed and skilled workmen are necessary. For these reasons the cost of the lamp is considerable.

### New Invoice Forms and Consular Certificates Proposed

The Treasury Department has under consideration the preparation of a new invoice form and consular certificate. Changes are proposed which will be of interest to the import trade. Before being issued, however, they are to be submitted to the forms committee at the New York Custom House for approval. This committee has consented to submit these forms to the committee on customs of the National Council of American Importers and Traders, Inc., before they are finally promulgated.

## Record Output of Fullers Earth in 1923

The largest output on record of fullers earth is reported by the Department of the Interior, through the Geological Survey, working in co-operation with the State Surveys in Alabama, Florida, Georgia and Illinois. Fifteen operators and six states reported that 149,134 short tons of fullers earth was sold in 1923, valued at $2,247,523, or $15.07 a ton. This output is 7 per cent greater than that of 1922, but it is nearly four times the output of 1913. The value of the output for 1923 was the third largest that has ever been recorded and was exceeded only by that of 1920 and 1922. It was six times as large as that of 1913.

The South continues to produce the greater part of the output. Florida was the leading state in output and value, as it has been from the beginning of the industry. Georgia was second and Texas was third in output and value. These three states reported about 92 per cent of the output and value in 1923. The producing states in the order of their output were Florida, Georgia, Texas, Illinois, Massachusetts and Alabama.

Imports of fullers earth, which at one time constituted the entire supply, reached their maximum quantity in 1914; since then they have on the whole declined and reached their lowest quantity in more than 25 years, 8,547 tons. The value in 1923 was $113,944, or $13.33 a ton. The value of imported fullers earth in 1923 was the lowest since 1909.

## Canadian Company Will Build New Paper Mill

The E. B. Eddy Co., of Hull, Que., Canada, has announced plans for alterations and additions to its plant which call for the expenditure of approximately $2,000,000. A new paper mill will be erected, with initial installation of one machine of 100 tons daily capacity. The sulphite plant will be brought up to a capacity of 60 to 75 tons per day, and extensive alterations and additions are to be made to the steam ground wood plants.

## Deliveries of German Dyes on Reparations Account

A report from abroad states the deliveries to date of German dyestuffs on account of reparations amounted to 23,190,875 kilos, divided as follows: British Empire, 7,664,000 kilos; Italy, 6,274,601 kilos; France, 4,276,601 kilos; Belgium, 4,219,214 kilos; Japan, 679,313 kilos; Serbia, 10,140 kilos; Greece, 67,006 kilos.

## List of Dye Standards Extended

The Treasury Department has issued its third supplemental list of dye standards for the purpose of administering the coal-tar paragraph of the tariff act. The third list contains seven additional dyes for purposes of comparison and adds seven additional names of dyes corresponding to dyes already adapted as standards.

## Personal

R. D. BEAN has been appointed chief engineer of the Brown Instrument Co., Philadelphia, Pa.

THOMAS BEER, for 11 years chief chemist of the Andrew Jergen Soap Co., is now in the technical department of the Essential Oil Co. of America, Groveland, Fla.

N. HENRY BLACK has recently been appointed assistant professor in Harvard University to teach physics and give courses to prepare science teachers for secondary schools. Mr. Black has been the science master in the Roxbury Latin School (Boston) for 25 years and is well known for his text books on physics, electricity and chemistry.

J. J. R. BRISTOW, for 5 years chemical supervisor of glycerine, fatty acid, alkalis, etc., of Procter & Gamble, is now in the technical department of the Essential Oil Co. of America.

Dr. R. ADAMS DUTCHER, head of the department of chemical agriculture and biological chemistry, Pennsylvania State College, gave an address before the members of the Allentown (Pa.) Rotary Club, at Hotel Allen, June 27, on the subject "The Human Chemical Plant."

J. E. FOLSE, sugar engineer, has become connected with the Magnolia Planting & Manufacturing Co., at its Magnolia mill, Terrebonne Parish, La., where he will be in charge of the sugar house.

W. S. FRISBIE, chemist in charge of co-operation, Bureau of Chemistry, United States Department of Agriculture, is now in California in connection with his duties.

Sir ERIC GEDDES, chairman of the board of directors, Dunlop Tire & Rubber Co., London, England, has arrived in the United States for an inspection of the company's plant at Buffalo, N. Y.

C. J. GUNDLACH, president of the Mississippi Wire Glass Co., New York, has left for a trip to Europe, to be absent about 2 months. He is accompanied by his wife and daughter.

MELVIN R. R. HUMMEL, of Baltimore, Md., was appointed chemist at the laboratory of the Dextro Products, Inc., Buffalo, N. Y., effective July 1.

LESTER LELAND, vice-president and vice-chairman of the executive committee of the United States Rubber Co. and affiliated interests, has resigned. He has been connected with the company for the past 32 years.

W. L. MUNRO, president of the American Window Glass Co., Pittsburgh, Pa., has returned to his desk from a trip abroad.

F. N. PICKETT, former expert in the chemical division of the British Army, has arrived in this country for a visit. He is said to have developed a new poison liquid for the extermination of the boll weevil, to which he will give attention while in the United States.

WILLIAM VOELKEL, a recent graduate of the University of Cincinnati, is now in the technical department of the Essential Oil Co. of America.

## Decline in Alcohol Production of Poland

The production of alcohol in Poland during the year 1923 amounted to 881,500 hectoliters, compared with 1,963,000 in Germany, and 1,564,831 in France. The Polish 1922 output, 598,100 hectoliters, showed a decided decrease from 2,742,300 in 1914. Active distilleries in 1914 numbered 2,510, while in 1922 there were 1,131. The decreased production was due chiefly to war damage, especially in Galicia, and, in a lesser degree, in Congress, Poland, and the eastern districts. Other factors tending to limit the output were adverse legislation, the monopoly policy of 1919 to 1921, and national excise taxes, as well as high production costs and business uncertainty.

This report, based on information compiled by L. J. Cochrane of the trade commissioner's office at Warsaw, states that of the pre-war total of 2,510 distilleries in Poland, 2,485 were agricultural, producing approximately 2,690,000 hectoliters, or 98.2 per cent. During 1923, there were 1,202 distilleries in operation, of which 1,155 were agricultural, producing 806,760 hectoliters (90.8 per cent), compared with 47 industrial distilleries, producing 74,760 hectoliters, or 9.2 per cent. The relative production of industrial distilleries is expected to increase, because of the increasing quantities of molasses made available to them, and also because they are able to undersell the agricultural.

## Obituary

FRED W. McNAIR, president of the Michigan College of Mines, was killed in a railroad accident at Buda, Ill., June 30. He was at one time president of the Society for the Promotion of Engineering Education.

C. M. O'DELL, former resident engineer of the Dominion Coal Co. and for the past year an official of the British Empire Steel headquarters staff, died at his home in Sydney, N. S., June 24, after an illness of many months.

JOHN HARVEY SETTLES, of Quincy, Mass., well known in the plate glass industry, died at the home of his daughter at Beaver, Pa., June 26, aged 65 years. He was connected at various times with the Opalite Tile Co., Monaca, Pa.; Pittsburgh Plate Glass Co., Crystal City, Pa., and the Standard Plate Glass Co., Boston, Mass. He resigned as superintendent for the last-named company about a year ago to enter business for himself. He is survived by his wife, two sons and three daughters.

ADOLPH B. SPRECKELS, of San Francisco, Calif., well-known sugar manufacturer, died at his home in that city, June 28, aged 67 years. He was vice-president of the J. D. Spreckels & Brothers Co., and was identified with the J. D. & A. B. Spreckels Sugar Co. and the Spreckels Sugar Co. of California. He was the son of Claus Spreckels, founder of the sugar industries bearing this name in California and the Hawaiian Islands.

# Market Conditions

## Moderate Improvement Reported in Demand for Chemicals

### Inquiry More Active for Home and Export Deliveries—Prices Continue to Show Irregularity Under Liberal Offerings

REPORTS from industrial centers were more favorable in the past week. Some textile and paper mills which had been closed resumed operations. Stocks of leather also were reported to have been reduced and a better feeling pervaded the market for chemical products although there was not much change for the better in the amount of business placed. However, small lot buying was more consistent and export inquiry helped to create a better feeling among sellers.

Most selections are in liberal supply and this condition has much to do with preventing steadiness in prices. As a result buyers frequently can shade the open quotations and selling competition is still a prominent factor. Calcium arsenate is in an unfavorable position with heavy stocks weakening values. Arsenic has been held on a steadier basis recently and has sold in a fairly large way for later deliveries with domestic producers prominent in such transactions.

In the acid group a good outlet has been found for citric and recent reductions in prices for domestic makes have turned attention in that direction, although imported offerings are competing keenly. Tartaric acid also has sold more freely with the preference given to the imported because of price considerations. Boric acid is moving steadily with prices somewhat unsettled because of the persistence of sellers. Mineral acids are working slowly into a better position but reserve stocks are still large and prices reflect this condition.

Alkalis were moderately active during the week. Caustic soda is quoted on a uniform price level by most producers but reports of shading are frequent and sales for export were made last week below the general asking price. Bleaching powder has not shown the general weakness which existed at this time last year and as far as first hands are concerned, the price has been well stabilized.

### Potashes

**Bichromate of Potash** — There has been a disposition on the part of some sellers to stiffen prices and to establish 9⅜c. per lb. as an inside trading basis. Demand, however, has been irregular and there was no difficulty in finding offerings at 9⅜c. per lb., with reports that this figure might be bettered on firm business.

**Caustic Potash** — Prices asked for domestic caustic are too high in com-

parison with ruling values for imported and the latter holds its position of vantage. Prices for imported vary according to seller. In some instances 6⅜c. per lb. is given as a firm figure for spot holdings but there are sellers at 6¼c. per lb. and buying has not been heavy enough to cause any uplift to values.

**Permanganate of Potash**—This material remained quiet. No open change in prices has been announced but lack of consuming interest has depressed the market and trade factors say that spot permanganate can be bought under the general quotation of 14c. per lb.

**Prussiate of Potash**—Red prussiate is dull but the quotations of sellers are about unchanged and 37½@40c. per lb.,

---

| "Chem. & Met." Weighted Index of Chemical Prices |
| :--- |
| Base = 100 for 1913-14 |

| | |
| :--- | ---: |
| This week | 156.06 |
| Last week | 155.05 |
| July, 1923 | 171.00 |
| July, 1922 | 156.00 |
| July, 1921 | 148.00 |
| July, 1920 | 274.00 |
| July, 1919 | 231.00 |
| July, 1918 | 277.00 |

Crude cottonseed oil sold at a new high for the movement and this more than offset weakness in miscellaneous chemicals. The index number advanced 101 points.

---

according to seller and quantity, is repeated as representing market values. Yellow prussiate appears to be a little easier as there are reports that 18½c. per lb. is not firm for spot goods. The latter is still quoted by sellers but on firm bids lower prices can be found. Shipments from abroad are said to be easy at 18c. per lb.

### Sodas

**Bichromate of Soda** — Competition among sellers was more in evidence and values reacted accordingly. Second hands were reported to be offering at 7¼c. per lb. and while producers were asking 7½c. per lb. it was stated that they were meeting the lower price. Basic conditions in the market have changed but little and present consumption is said to be relatively light owing to depression in consuming trades.

**Caustic Soda**—Sales for export were made last week at 2.80c. per lb. and at 2.85c. per lb. This is not a general quotation as 3c. per lb., f.a.s. was quoted by different sellers. Inquiry for export was more active and domes-

tic buyers also were said to be showing more interest in the market. No change has been made in the contract price for domestic delivery and 3.10c. per lb. is quoted for drums, carlots, at works.

**Nitrate of Soda**—Business has been held to small lots due to the fact that stocks on hand are small and also because lower prices for later deliveries have held demand for spot goods to actual necessities. Interest in forward positions is quiet and shipments from Chile during June are reported to have been comparatively light. Current prices for nitrate are $2.60 per 100 lb. for spot and $2.35@$2.37 for July and August shipments.

**Nitrite of Soda**—Prices are showing a range according to seller. The lowest figure heard is 8½c. per lb. ad asking prices go up to 9c. per lb. Buyers are not active and contract deliveries are said to be supplying the major part of domestic requirements.

**Prussiate of Soda**—Reports have been current to the effect that shipments of imported prussiate were offered at close to 9c. per lb. The spot market has been easy and 9½c. per lb. has been openly quoted without proving an inducement to buyers. Domestic prussiate is commanding a premium over the imported but there is a difference of views regarding the attitude of domestic sellers and in some instances they are credited with meeting the competition of importers.

### Miscellaneous Chemicals

**Acetone**—In some quarters an easier market was looked for, following the recent decline in some of the wood distillation products. The open quotation has been maintained at 15@16c. per lb. These prices are regarded by producers as low when judged by producing costs.

**Alum**—Reports of a firm market have been circulated with curtailed production given as a steadying factor. These reports are hardly borne out by the attitude of sellers. Both domestic and foreign grades are in large supply and the slow demand from consuming trades gives an easy tone to values. Potash, lump, of foreign origin is said to be available at 2¾c. per lb. with domestic at 3c. per lb. Ammonia alum is offered at 3½c. per lb. for lump, and 3.60c. per lb. for ground.

**Arsenic**—Sales of small lots of imported were made at 7¼c. per lb. in the spot market. This price also was asked for larger amounts and 8c. per lb. was an inside figure for domestic arsenic. Demand was less active than in the past two weeks but prices are well established at the quoted levels and price cutting is no longer in evidence. A sale of Japanese arsenic for forward delivery was made recently at

7½c. per lb. but the best price named last week was 7½c. per lb.

**Calcium Arsenate**—Dealers in Southern sections are reported to be selling arsenate steadily and reports agree that total consumption for this crop year will be larger than ever before. In spite of this, the market is dull and prices have been cut to a point where the business is not profitable for most manufacturers. There is no stability to prices and buyers are able to obtain deliveries at 9½c. per lb. delivered Southern points. Carlots at producers works are offered at 9c. per lb. and the large stocks on hand are regarded as making improbable, any recovery from that price level.

**Copper Sulphate**—Considerable quantities changed hands last week. Stocks appear to be large and sellers were eager to book whatever business was in sight. One lot of imported sulphate sold at private terms with the price reported to be very low.. The asking price for imported on spot was 4.20c. per lb. and shipments were offered at 4½c. per lb. with a possibility that 4c. per lb. could be done. Domestic sulphate sold at 4.40c. per lb. and the price ranged up to 4.65c. per lb. according to seller.

**Epsom Salts**—Arrivals from foreign markets have been liberal but buying orders have been fairly steady and the market has been influenced by reports of firm conditions abroad. The quotation for imported technical salts was $1.30@$1.40 per 100 lb. but the inside quotation was not free and $1.35 per 100 lb. was the best price named in some quarters.

**Formaldehyde**—This material is featured by a difference in price according to seller. Asking prices for carlots vary from 9c. to 9½c. per lb. Small lots are available at 9½c. per lb.

### Coal-Tar Products

The output of byproduct coke has not been curtailed to quite the same extent as beehive coke, but restrictions nevertheless have been sufficient to support the market for light oils and bring about a rather firm tone. The fact that stocks of gasoline are of record proportions has little or no influence on traders in benzene, supplies of the latter being comparatively small. Price changes in the market were few. Interest centered in phenol, some sellers being in a more favorable position to offer supplies for immediate delivery. Naphthalene, refined, was weak on forced selling.

**Benzene**—Stocks continue light and this served to steady prices in all directions. Leading producers offered 90 per cent material at 23c. per gal., and the pure at 25c. per gal., tank cars, f.o.b. works. Demand was fair.

**Cresylic Acid**—Prices were unsettled on keen competition. There were sellers of the 97 per cent grade at 63@68c. per gal., the price depending upon the color and quantity involved. Several parcels arrived from English ports in the past week.

**Naphthalene**—Refined was easy on rather liberal offerings of spot goods. Flake, white, was traded in at 4½c. per lb. On carload lots this figure might have been shaded. Chips closed nominally at 4½@4½c. per lb. Crude, to import, was quiet at 2c. per lb., c.i.f. New York.

**Phenol**—Spot U.S.P. phenol sold at 26c. per lb., with additional offerings at this figure from several sources. The undertone was easy, reflecting quiet trading conditions. According to producers surplus stocks are not large. On forward deliveries it was possible to obtain U.S.P. material at 25c. per lb., a decline of 1c.

**Solvent Naphtha**—Trading was described as routine only, but limited production tends to steady prices. Water white was nominally unchanged at 25c.

per gal., with crude at 22c. per gal., tank cars, f.o.b. works.

### Alcohol

There were no additional changes in the selling schedule. Withdrawals of denatured alcohol against existing contracts were good, but new business continues inactive. Special denatured, formula No. 1, 190 proof, was offered at 42@44c. per gal, in drums.

Methanol met with a moderate call only, notwithstanding the recent reduction in price. Pure was offered by first hands at 75c. per gal., tank cars, 78c. per gal., in drums and 83c. per gal. in bbl.

# Vegetable Oils and Fats

### Cottonseed Oil Advances—Good Trading in Linseed Oil—Sharp Uplift in China Wood Oil—Crude Corn Higher

HIGHER prices for corn and lard, together with reports of fairly good cash demand, strengthened the market for cottonseed oil and new highs were established for the movement before the close of the week. Crushers sold at least one round lot of linseed oil to a linoleum maker, while the paint trade also came in for additional supplies. Coconut oil was inactive but fairly steady at the recent advance. China wood oil scored gains on covering by shorts. Crude corn and palm oils were higher.

**Cottonseed Oil**—Trading in the options for refined oil was more active, and, inspired by the better feeling in grains and provisions, prices moved upward. On Thursday July prime summer yellow oil closed at 11.35c. bid and 11.50c. asked, with September at 11.22c. bid and 11.24c. asked. December oil (new crop) was 9.36c. bid and 9.39c. asked. Crude oil closed at 9½@9¾c. per lb., tank cars, mills, actual business passing at the top figure. The cotton outlook remains favorable, but this has no apparent influence on old crop oil. Lard compound was firm at 12¾@13c. per lb. Pure lard in Chicago

---

*Flaxseed Crop Estimated at 25,900,000 Bu.*

The first report on production of flaxseed in the United States was made by the Department of Agriculture on July 9 and places the estimated yield at 25,900,000 bu., which compares with 18,000,000 bu. in the July forecast a year ago. The condition of the crop on July 1 was 86.8 per cent of normal, which compares with 85 per cent a year ago and 85.1 per cent the 10-year average. The yield per acre was placed at 7.7 bu.

Final acreage and production figures for the past 5 years, together with the first preliminary estimate for 1924, follow:

| | Acres | Bushels |
|---|---|---|
| 1924 | 3,375,000 | 25,900,000 |
| 1923 | 2,061,000 | 17,429,000 |
| 1922 | 1,113,000 | 10,375,000 |
| 1921 | 1,108,000 | 8,029,000 |
| 1920 | 1,757,000 | 10,774,000 |
| 1919 | 1,503,000 | 7,256,000 |

---

settled at 11.57c. per lb., cash, which compares with 10.80c. per lb. a week ago.

**Linseed Oil**—The first preliminary report on the flaxseed crop was very much in line with expectations and had little affect on the market. Consumers regarded the report as bearish, while crushers were not inclined to take a definite stand just at this time, as weather conditions later in the season will determine the actual yield. According to trade authorities consumption of linseed oil over the first 6 months of the year was at the rate of 36,000,000 bu. for the entire year. Some good buying of oil took place in the past week. A linoleum maker took on 50,000 gal. on the tank car basis of 88c. per gal., August delivery, equal to 94c. per gal. in cooperage. Paint makers purchased several cars of August at 94c., while September sold at 92c. per gal., cooperage included. October forward was nominal at 88c., cooperage basis. Linseed cake for export advanced to $38 per ton, f.a.s. New York.

**China Wood Oil**—Covering by shorts and some buying for varnish makers caused prices to advance sharply. Tank cars sold at 12¾c., f.o.b. Pacific Coast. Spot oil, in bbl., New York, was raised to 14@14½c. per lb.

**Corn Oil**—Crude oil sold at 9¾c., tank cars, f.o.b. point of production.

**Coconut Oil**—Market quiet, but firm. Ceylon type 8@8½c., tanks, coast, and 8½c., tanks, New York.

**Palm Oil**—Lagos advanced to 7⅝c. per lb., spot, and 7.54c. per lb., future delivery. Niger oil firm at 7½c. per lb.

**Sesame Oil**—Refined on spot sold at 11@11½c. per lb.

**Menhaden Oil**—Crude oil sold at 37½c. per gal., tank cars, factory. Fishing in the past week poor.

**Tallow, etc.**—Sales of goods equal to extra special tallow took place at 7½c. per lb., ex plant. Market firm. Yellow grease, 8 per cent acid, sold at 7c. per lb.; 25 per cent acid brought 6½c. per lb. Oleo stearine firm at 12½c. per lb. Soaplye crude glycerine, basis 80 per cent, sold at 10¾c. per lb., loose, f.o.b. point of production.

# Imports at the Port of New York

### July 3 to July 10

**ACIDS — Cresylic** — 12 dr., Liverpool, Sherlow Chemical Co.; 44 dr., Liverpool, W. E. Jordan & Bro.; 1 dr., Antwerp, Lunham & Reeve. **Boracic**—200 bg., Leghorn, Pacific Coast Borax Co. **Formic**—140 bx., Rotterdam, R. W. Greeff & Co. **Oxalic**—33 csk., Christiania, Roessler & Hasslacher Chemical Co.; 40 csk., Hamburg, Seaboard Natl. Bank. **Phenol**—10 dr., Antwerp, Lunham & Reeve.

**ALCOHOL** — 200 bbl. and 35 dr. denatured, Arecibo, Order; 100 bbl. denatured, San Juan, C. Esteva.

**AMMONIUM CARBONATE** — 32 csk., Glasgow, La Curto & Funk; 20 csk., Liverpool, Order.

**AMMONIUM NITRATE**—624 csk. and 20 bg., Hamburg, Kuttroff, Pickhardt & Co.

**ANTIMONY REGULUS**—250 cs., Shanghai, Wah Chang Trading Corp.

**ANTIMONY ORE**—950 bg., Antofagasta, Bank of Tarapaca & Argentina.

**ARSENIC**—200 cs., Kobe, Order; 350 cs. (at San Francisco), Kobe, Order; 200 csk., Hamburg, R. W. Greeff & Co.

**BARIUM CARBONATE**—300 bg., Hamburg, Roessler & Hasslacher Chem. Co.

**BARIUM CHLORIDE**—82 bbl., Rotterdam, Goldschmidt Corp.; 30 csk., Rotterdam, A. Klipstein & Co.; 62 csk., Hamburg, Seaboard Natl. Bank.

**BARYTES**—250 bg., Rotterdam, Schall Color & Chemical Co.

**BAUXITE** — 487,000 kilos, Rotterdam, Bank of America.

**BONE CHAR**—1,435 bg., Antilla, Foundation Co.

**CALCIUM CHLORIDE**—76 dr., Hamburg, C. Hardy, Inc.

**CALCIUM NITRATE**—73 csk., Christiania, Order.

**CAMPHOR** — 100 cs. crude, Shanghai, Eastman Kodak Co.; 90 bbl., Hamburg, Nixon Nitration Works.

**CASEIN**—343 bg., Buenos Aires, Order.

**CHALK** — 900 bg., Antwerp, Bankers Trust Co.; 260 bg., Bristol, H. J. Baker & Bros.; 500 bg., Antwerp, Reichard-Coulston, Inc.; 1,000 bg., Antwerp, Order; 543,000 kilos, Dunkirk, Taintor Trading Co.

**CHEMICALS** — 20 cs., Hamburg, E. Dietzgen Co.; 24 pkg., Hamburg, Jungmann & Co.; 349 pkg., Hamburg, Pfaltz & Bauer; 84 csk., London, Toch Bros.; 23 csk., Bremen, Order; 49 csk., Hamburg, Jungmann & Co.; 62 pkg., Rotterdam, Merck & Co.; 169 csk., Rotterdam, H. Kastor; 96 cs., Trieste, Happel & McAvoy; 20 cs., London, Order; 32 cs., Hamburg, Natl. Am. Bank.

**CHINA CLAY**—62 tons, Fowey, Moore & Munger; 1,860 tons, Fowey, English China Clay Sales Corp; 200 tons, Fowey, Hammill & Gillespie; 350 bg., Bristol, National City Bank; 200 tons, Bristol, Moore & Munger; 564 tons, Bristol, Moore & Munger; 40 tons, Bristol, Paper Makers Import Co.

**COLORS**—15 csk. earth, Hamburg, H. J. Baker & Bro.; 10 pkg. aniline, Hamburg, Franklin Import & Export Co.; 5 csk. do., Hamburg, Bernard Judae & Co.; 10 csk., Southampton, American Exchange National Bank; 330 bg. earth, Leghorn, Reichard-Coulston, Inc.; 27 bg. do., Leghorn, Order; 15 cs. bronze, Bremen, Bank of the Manhattan Co.; 10 bbl. dry, Bremen, H. R. Jahn; 2 bbl. dr., Bremen, Kuttroff, Pickhardt & Co.; 6 bbl. aniline, Bremen, Order; 40 pkg. aniline, Havre, Ciba Co., Inc.; 69 cylinders do., Havre, Sandoz Chemical Works; 12 csk. do., Genoa, Irving Bank-Col. Trust Co.; 21 pkg. aniline, Rotterdam, Kuttroff, Pickhardt & Co.; 7 pkg. do., Rotterdam, H. A. Metz & Co.; 23 cs. bronze, Bremen, Gerstendorfer Bros.; 11 bbl. aniline, Havre, Wallerstein Lab.

**COPPER OXIDE**—20 dr. Hamburg, C. B. Richard & Co.; 15 dr., Hamburg, Order.

**CORUNDUM ORE**—146 bg., Beira, E. S. Regelman; 416 bg., Durban, Standard Bank of South Africa.

**DIVI-DIVI** — 818 bg., Maracaibo, R. Desvernine; 700 bg., Pampatar, Standard Commodities Co.; 614 bg., Pampatar, Eggers & Heinlein.

**IRON CHLORIDE**—35 bbl., Hamburg, Roessler & Hasslacher Chem. Co.

**EPSOM SALT**—500 bg., Hamburg, H. J. Baker & Bro.; 40 bbl., Hamburg, Brown & Roese; 1,000 bg., Hamburg, Diener, Blank & Co.

**FLUORSPAR** — 1 lot (in bulk), Cape Town, Standard Bank of South Africa.

**FUSEL OIL**—3 bbl., Rotterdam, American Express Co.; 2 bbl., San Juan, Order.

**FUSTIC** — 959 pcs., San Juan, C. H. Pearson & Son.

**GLYCERINE**—30 dr. crude, Genoa, Order.

**GRAPHITE**—476 bg., Marseilles, H. W. Peabody & Co.; 50 dr., Genoa, Order.

**GUMS**—40 bg. copal, Antwerp, Order; 20 bg. copal, London, Chemical National Bank; 13 bg. do., London, S. Winterbourne & Co.; 2 bg. kauri, London, Order; 242 bg. copal, Manila, Innes & Co.; 210 bg. copal, Antwerp, Brown Bros. & Co.

**IRON OXIDE** — 75 bbl., Marseilles, Reichard-Coulston, Inc.; 20 csk. and 10 kegs, Liverpool, J. H. Rhodes & Co.; 31 csk., Liverpool, J. A. McNulty; 50 bbl., Bristol, G. Collins & Co.; 151 bg., Bristol, Order; 29 csk., Bristol, Order; 21 csk., Liverpool, L. H. Butcher & Co.; 26 csk., Liverpool, J. A. McNulty; 65 csk., Liverpool, Reichard-Coulston, Inc.; 5 csk., Liverpool, Order.

**KAOLIN**—599 bg., Hamburg, Lunham & Moore; 150 bbl., Hamburg, Roessler & Hasslacher Chem. Co.

**LITHOPONE** — 40 csk., Rotterdam, Reichard-Coulston, Inc.; 100 csk., Antwerp, E. M. & F. Waldo; 45 bbl., Hamburg, Nixon Nitration Works.

**MANGANESE OXIDE**—10 csk., Hamburg, Order.

**MAGNESIUM CHLORIDE** — 100 dr., Hamburg, Diener, Blank & Co.; 547 dr., Hamburg, Innis, Speiden & Co.

**MAGNESIUM FLUORIDE** — 24 bbl., Hamburg, J. Sonneborn, Inc.

**MAGNESITE** — 106 bbl., Rotterdam, Speiden, Whitfield Co.; 250 bg., Rotterdam, A. Kramer & Co.; 122 bbl., 200 bg., Rotterdam, Brown Bros. & Co.; 150 bg., Hamburg, Order.

**MANGANESE ORE**—2,200 tons, Rio de Janeiro, U. S. Steel Products Co.

**NAPHTHALENE** — 70 bg., Rotterdam, Lunham & Reeve; 36 bg., Hamburg, E. M. Sergeant & Co.

**OILS—Castor**—56 bbl., Hull, Order: **Cod** —100 bbl., Hull, Order; 50 bbl., Liverpool, Order. **China Wood**—150 bbl., Shanghai, Viele, Blackwell & Buck; 500 bbl., Shanghai, Gillespie & Sons. **Olive Foots** (sulphur oil) 250 bbl., Bari, E. Suter & Co.; 250 bbl., Bari, National City Bank; 2 tanks, Bari, Palmolive Co. **Palm Kernel**—60 bbl., Hull, Order. **Palm**—14 csk., Hamburg, African & Eastern Trading Co.; 556 dr., Antwerp, Holder of Bill of Lading. **Rapeseed**—30 bbl., Hull, Bank of America; 280 bbl., Hull, J. C. Francesconi & Co.; 550 bbl., Hull, Order.

**OIL SEEDS—Linseed**—52,953 bg. and a quantity in bulk, Rosario, Order; 87,011 bg., Rosario, Spencer Kellogg & Sons; 16,933 bg., Buenos Aires, Spencer Kellogg & Sons; 2,638,964 kilos (in bulk), Santa Fe, Order; 57,320 bg. and 59,065 kilos (in bulk) Rosario, Order; 18,822 bg., Buenos Aires, Order.

**POTASSIUM SALTS**—27 bbl., Hamburg, Order; 19 csk. prussiate, Rotterdam, Innis, Speiden & Co.; 1016 bg. nitrate, Rotterdam, Kuttroff, Pickhardt & Co.; 250 csk. alum. Rotterdam, Superfos Co.; 37 csk. do., Rotterdam, A. Klipstein & Co.; 4 csk. bicarbonate, Rotterdam, Jungmann & Co.; 50 dr. caustic, Gothenburg, Order; 100 kegs chlorate, Antwerp, E. Suter & Co.; 27 kegs do., Antwerp, E. I. du Pont de Nemours & Co.; 12 cs. bromide, Antwerp, Fidelity International Trust Co.; 1,000 bg. sulphate, Antwerp and 849,885 kilos manure salt, Societe Comm. des Potasses d'Alsace; 461 pkg. caustic, Hamburg, A. Klipstein & Co.; 62 bbl. hydrate, Hamburg, Innis, Speiden & Co.; 1,500 csk. chlorate, Hamburg, Irving Bank-Col. Trust Co.; 291 dr. caustic, Hamburg, Roessler & Hasslacher Chem. Co.; 243 dr. caustic, Hamburg, Am. Exchange Nat'l Bank; 100 csk. alum, Hamburg, Cooper & Cooper; 670 cs. and 53 bbl. bromide, Hamburg, Order; 23 bbl. carbonate, Hamburg, Order; 1 lot muriate and 2 lots manure salt, Hamburg, Potash Importing Corp. of Am.

**PYRIDINE**—1 dr., Antwerp, Bernard, Judae & Co.

**QUICKSILER**—200 flasks, Genoa, Order; 40 flasks, Vera Cruz, Poillon & Poirier; 32 flasks, Tampico, G. Ramos.

**SAL AMMONIAC**—26 csk., Rotterdam, Order; 39 pkg., Hamburg, Roessler & Hasslacher Chem. Co.

**SHELLAC**—50 cs. garnet, Hamburg, Rogers-Pyatt Shellac Co.; 25 cs., Hamburg, Order; 84 bg., Marseilles, Order; 106 cs., Singapore, Brown Bros. & Co.; 588 cs., Bangkok, Order; 118 cs., Hamburg, Order.

**SODIUM SALTS**—300 bbl. chlorate, Hamburg, Seaboard National Bank; 10 csk. fluoride, Hamburg, Order; 200 csk. hyposulphite, Hamburg, Order; 106 cs. cyanide, Liverpool, Order; 112 dr. cyanide, Liverpool, Order; 154 bg. nitrate, Christiania, Order; 400 bbl. silico fluoride, Copenhagen, Order; 22 csk. phosphate, Order; 160 csk. hydrosulphite, Rotterdam, Kuttroff, Pickhardt & Co.; 72 s. chlorate, Antwerp, Globe Shipping Co.; 2 dr. caustic, Gothenburg, Order; 348 dr. cyanide, Liverpool, Order; 7,333 bg. nitrate, Iquique, E. I. du Pont de Nemours & Co.; 11,715 bg. do., Iquique, Antony Gibbs & Co.; 23 csk. prussiate, Liverpool, C. Tennant Sons & Co.; 100 csk. hyposulphite, Hamburg, Order; 25 csk. nitrate, Hamburg, Kuttroff, Pickhardt & Co.

**SUMAC**—210 bg., Palermo, Order; 420 bg. ground, Palermo, Order.

**TALC**—150 bg., Genoa, Bankers Trust Co.; 500 bg., Genoa, Italian Discount & Trust Co.; 500 bg., Genoa, Italian Discount & Trust Co.

**TARTAR**—582 bg., Marseilles, C. Pfizer & Co.; 205 bg., Marseilles, Royal Baking Powder Co.; 122 bg., Rotterdam, C. Pfizer & Co.; 114 csk., Catania, Tartar Chemical Works.

**TETRACHLORATHAN**—108 dr. Hamburg, Roessler & Hasslacher Chem. Co.

**WATTLE BARK**—4,357 bg., Durban, Tannin Corp.

**WAXES**—22 cs. beeswax, Constantinople, Order; 35 cs. do., Hamburg, National City Bank; 22 bg. ceresin, Hamburg, Order; 255 bg. ozokerite, Hamburg, J. Dick; 400 bg. paraffine, London, Order; 128 bg. ozokerite, Hamburg, J. Dick; 12 bg. beeswax, Baracoa, R. Desvernine; 40 bg. do., Baracoa, Order; 139 bg. beeswax, Valparaiso, Duncan Fox & Co.; 25 bg. do., Valparaiso, Order; 26 bg. do., Havana, Order; 111 bg. carnauba and 51 bg. beeswax, Rio de Janeiro, American Trading Co.; 50 cs. beeswax, Hamburg, Brown Bros. & Co.; 290 bg. montan, Hamburg, Coal & Iron Nat'l Bank.

**WOOL GREASE** — 200 bbl., Bremen, Pfaltz & Bauer.

# Current Prices in the New York Market

## For Chemicals, Oils and Allied Products

THESE prices are for the spot market in New York City, but a special effort has been made to report American manufacturers' quotations whenever available. In many cases these are for material f.o.b. works or on a contract basis and these prices are so designated. Quotations on imported stocks are reported when they are of sufficient importance to have a material effect on the market. Prices quoted in these columns apply to large quantities in original packages.

## General Chemicals

| | | | |
|---|---|---|---|
| Acetone, drums, wks | lb. | $0.15 – | $0.15¼ |
| Acetic anhydride, 85%, dr | lb. | .34 – | .36 |
| Acid, acetic, 28%, bbl | 100 lb. | 3.12 – | 3.37 |
| Acetic, 56%, bbl | 100 lb. | 5.85 – | 6.10 |
| Acetic, 80%, bbl | 100 lb. | 8.19 – | 8.44 |
| Glacial, 99½%, bbl | 100 lb. | 11.01 – | 11.51 |
| Boric, bbl | lb. | .09 – | .09¼ |
| Citric, kegs | lb. | .46 – | .46¼ |
| Formic, 85% | lb. | .12½ – | .13 |
| Gallic, tech | lb. | .45 – | .50 |
| Hydrofluoric, 52%, carboys | lb. | .11 – | .12 |
| Lactic, 44%, tech., light, bbl | lb. | .12½ – | .13 |
| 22% tech., light, bbl | lb. | .06 – | .06¼ |
| Muriatic, 18° tanks | 100 lb. | .80 – | .85 |
| Muriatic, 20°, tanks | 100 lb. | .95 – | 1.00 |
| Nitric, 36°, carboys | lb. | .04 – | .04½ |
| Nitric, 42°, carboys | lb. | .04½ – | .05½ |
| Oleum, 20%, tanks | ton | 16.00 – | 17.00 |
| Oxalic, crystals, bbl | lb. | .10 – | |
| Phosphoric, 50% carboys | lb. | .07 – | .08 |
| Pyrogallic, resublimed | lb. | 1.55 – | 1.60 |
| Sulphuric, 60°, tanks | ton | 9.00 – | 10.00 |
| Sulphuric, 60°, drums | ton | 12.00 – | 13.00 |
| Sulphuric, 66°, tanks | ton | 13.00 – | 14.00 |
| Sulphuric, 66° drums | ton | 17.00 – | 18.00 |
| Tannic, U.S.P., bbl | lb. | .65 – | .70 |
| Tannic, tech., bbl | lb. | .45 – | .50 |
| Tartaric, imp., powd., bbl | lb. | .27 – | .28 |
| Tartaric, domestic, bbl | lb. | .30 – | |
| Tungstic, per lb | lb. | 1.20 – | 1.25 |
| Alcohol, butyl, drums, f.o.b. works | lb. | .25 – | .30 |
| Alcohol ethyl (Cologne spirit), bbl | gal. | 4.83 – | |
| Ethyl, 190 p'f. U.S.P., bbl | gal. | 4.81 – | |
| Alcohol, methyl (see Methanol) | | | |
| Alcohol, denatured, 190 proof | | | |
| No. 1, special bbl | gal. | .49 – | |
| No. 1, 190 proof, special, dr | gal. | .43 – | |
| No. 1, 188 proof, bbl | gal. | .52 – | |
| No. 1, 188 proof, dr | gal. | .46 – | |
| No. 5, 188 proof, bbl | gal. | .48 – | |
| No. 5, 188 proof, dr | gal. | .42 – | |
| Alum, ammonia, lump, bbl | lb. | .03½ – | .04 |
| Potash, lump, bbl | lb. | .02½ – | .03½ |
| Chrome, lump, potash, bbl | lb. | .05½ – | .06 |
| Aluminum sulphate, com. bags | 100 lb. | 1.35 – | 1.40 |
| Iron free bags | | 2.35 – | 2.45 |
| Aqua ammonia, 26°, drums | lb. | .06½ – | .06¾ |
| Ammonia, anhydrous, cyl | lb. | .28 – | .30 |
| Ammonium carbonate, powd. tech., casks | lb. | .12 – | .13 |
| Ammonium nitrate, tech., casks | lb. | .09 – | .10 |
| Amyl acetate tech., drums | gal. | 2.95 – | 3.00 |
| Antimony oxide, white, bbl | lb. | .10 – | .10½ |
| Arsenic, white, powd., bbl | lb. | .07½ – | .08 |
| Arsenic, red, powd., kegs | lb. | .14½ – | .15½ |
| Barium carbonate, bbl | ton | 61.00 – | 62.00 |
| Barium chloride, bbl | ton | 79.00 – | 82.00 |
| Barium dioxide, 88%, drums | lb. | .17½ – | .18 |
| Barium nitrate, casks | | .08½ – | .08½ |
| Blanc fixe, dry, bbl | lb. | .03½ – | .04 |
| Bleaching powder, f.o.b. wks. drums | 100 lb. | 1.90 – | |
| Spot N. Y. drums | 100 lb. | 2.20 – | 2.25 |
| Borax, bbl | lb. | .05 – | .05½ |
| Bromine, cases | lb. | .34 – | .38 |
| Calcium acetate, bags | 100 lb. | 3.00 – | 3.05 |
| Calcium arsenate, dr | lb. | .09 – | .09½ |
| Calcium carbide, drums | lb. | .05 – | .05½ |
| Calcium chloride, fused, dr.wks. | ton | 21.00 – | |
| Gran. drums works | ton | 27.00 – | |
| Calcium phosphate, mono, bbl | lb. | .06½ – | .07½ |
| Camphor, Jap. cases | lb. | .71 – | .72 |
| Carbon bisulphide, drums | lb. | .06 – | .06½ |
| Carbon tetrachloride, drums | lb. | .07 – | .07½ |
| Chalk, precip.—domestic, light, bbl | lb. | .04½ – | .04½ |
| Domestic, heavy, bbl | lb. | .03½ – | .04 |
| Imported, light, bbl | lb. | .04½ – | .05 |
| Chlorine, liquid, tanks, wks. | lb. | .04½ – | |
| Contract, tanks, wks | lb. | .04½ – | |
| Cylinders, 100 lb., wks | lb. | .05½ – | .07½ |
| Chloroform, tech., drums | lb. | .30 – | .32 |
| Cobalt, oxide, bbl | lb. | 2.10 – | 2.25 |
| Copperas, bulk, f.o.b. wks | ton | 16.00 – | 18.00 |
| Copper carbonate, bbl | lb. | .15½ – | .16 |
| Copper cyanide, drums | lb. | .45 – | .46 |
| Copper sulphate, dom., bbl | 100 lb. | 4.40 – | 4.60 |
| Imp bbl | 100 lb. | 4.20 – | |
| Cream of tartar, bbl | lb. | .20½ – | .21 |
| Epsom salt, dom., tech. bbl | 100 lb. | 1.75 – | 2.00 |
| Epsom salt, imp., tech. bags | 100 lb. | 1.30 – | 1.35 |
| Epsom salt, U.S.P., dom. bbl | 100 lb. | 2.10 – | 2.35 |
| Ether, U.S.P., dr concent'd | lb. | .13 – | .14 |
| Ethyl acetate, 85%, drums | gal. | .92 – | .95 |

| | | | |
|---|---|---|---|
| Ethyl acetate, 99%, dr | gal. | $1.08 – | $1.10 |
| Formaldehyde, 40%, bbl | lb. | .09 – | .09½ |
| Fullers earth—f.o.b. mines | ton | 7.50 – | 18.00 |
| Furfural, works, bbl | lb. | .25 – | |
| Fusel oil, ref., drums | gal. | 2.75 – | 3.50 |
| Fusel oil, crude, drums | gal. | 1.75 – | 2.00 |
| Glaubers salt, wks., bags | 100 lb. | 1.20 – | 1.40 |
| Glaubers salt, imp., bags | 100 lb. | .90 – | .95 |
| Glycerine, c.p., drums extra | lb. | .16½ – | .17 |
| Glycerine, dynamite, drums | lb. | .16½ – | |
| Glycerine, crude 80%, loose | lb. | .10½ – | .11 |
| Hexamethylene, drums | lb. | .65 – | .70 |
| Lead: | | | |
| White, basic carbonate, dry, casks | lb. | .09½ – | |
| White, basic sulphate, casks | lb. | .09½ – | |
| White, in oil, kegs | lb. | .11½ – | .12½ |
| Red, dry, casks | lb. | .10½ – | |
| Red, in oil, kegs | lb. | .12½ – | .13½ |
| Lead acetate, white crys., bbl | lb. | .14½ – | |
| Brown, broken, casks | lb. | .13½ – | |
| Lead arsenate, powd., bbl | lb. | .16 – | .18 |
| Lime-Hydrated, bg, wks | ton | 10.50 – | 12.50 |
| Bbl., wks | ton | 18.00 – | 19.00 |
| Lime, Lump, bbl | 280 lb. | 3.63 – | 3.65 |
| Litharge, comm., casks | lb. | .10 – | .10½ |
| Lithopone, bags | lb. | .06½ – | .06½ |
| Magnesium carb., tech., bags | lb. | .08½ – | .08½ |
| Methanol, 95%, bbl | gal. | .74 – | .76 |
| Methanol, 97%, bbl | gal. | .76 – | .78 |
| Methanol, pure, tanks | gal. | .75 – | |
| drums | gal. | .78 – | .80 |
| bbl | gal. | .83 – | .85 |
| Methyl-acetone, t'ks | gal. | .70 – | |
| Nickel sal., double, bbl | lb. | .09½ – | .10½ |
| Nickel salts, single, bbl | lb. | .10 – | .11 |
| Orange mineral, csk | lb. | .13½ – | .14½ |
| Phosgene | | .60 – | .75 |
| Phosphorus, red, cases | lb. | .70 – | .75 |
| Phosphorus, yellow, cases | lb. | .37½ – | .40 |
| Potassium bichromate, casks | lb. | .09½ – | .09½ |
| Potassium bromide, gran., bbl | lb. | .22 – | .38 |
| Potassium carbonate, 80-85%, calcined, casks | lb. | .05½ – | .05½ |
| Potassium chlorate, powd | lb. | .07½ – | .08½ |
| Potassium cyanide, drums | lb. | .47 – | .52 |
| Potassium, first sorts, cask | lb. | .07½ – | .08 |
| Potassium hydroxide (caustic potash) drums | lb. | .06½ – | .06½ |
| Potassium iodide, cases | lb. | 3.65 – | 3.75 |
| Potassium nitrate, bbl | lb. | .06 – | .07½ |
| Potassium permanganate, drums | lb. | .13½ – | .14 |
| Potassium prussiate, red, casks | lb. | .35 – | .38 |
| Potassium prussiate, yellow, casks | lb. | .18 – | .18½ |
| Salammoniac, white, gran., casks, imported | lb. | .06½ – | .06½ |
| Salammoniac, white, gran., bbl., domestic | lb. | .07½ – | .08 |
| Gray, gran., casks | lb. | .08 – | .09 |
| Salsoda, bbl | 100 lb. | 1.20 – | 1.40 |
| Salt cake (bulk) works | ton | 16.00 – | 18.00 |
| Soda ash, light, 58% flat, bulk, contract | 100 lb. | 1.25 – | |
| bags, contract | 100 lb. | 1.38 – | |
| Soda ash, dense, bulk, contract, basis 58% | 100 lb. | 1.35 – | |
| bags, contract | 100 lb. | 1.45 – | |
| Soda, caustic, 76%, solid, drums contract | 100 lb. | 3.10 – | |
| Soda, caustic, ground and flake, contracts, dr | 100 lb. | 3.50 – | 3.85 |
| Soda, caustic, solid, 76% f. a.s. N. Y. | 100 lb. | 2.85 – | 3.05 |
| Sodium acetate, works, bbl | lb. | .04½ – | .05 |
| Sodium bicarbonate, bulk | 100 lb. | 1.75 – | |
| 330-lb. bbl | 100 lb. | 2.00 – | |
| Sodium bichromate, casks | lb. | .07½ – | .07½ |
| Sodium bisulphate (niter cake) | ton | 6.00 – | 7.00 |
| Sodium bisulphite, powd., U.S.P., bbl | lb. | .04½ – | .04½ |
| Sodium chlorate, kegs | lb. | .06½ – | .07 |
| Sodium chloride | long ton | 12.00 – | 13.00 |
| Sodium cyanide, cases | lb. | .19 – | .22 |

| | | | |
|---|---|---|---|
| Sodium fluoride, bbl | lb. | $0.08½ – | $0.10 |
| Sodium hyposulphite, bbl | lb. | .02½ – | .02½ |
| Sodium nitrite, casks | lb. | .08½ – | .09 |
| Sodium peroxide, powd., cases | lb. | .23 – | .27 |
| Sodium phosphate, dibasic, bbl | lb. | .03½ – | .03½ |
| Sodium prussiate, yel. bbl | lb. | .09½ – | .10½ |
| Sodium salicylic, drums | lb. | .38 – | .40 |
| Sodium silicate (40°, drums) | 100 lb. | .75 – | 1.15 |
| Sodium silicate (60°, drums) | 100 lb. | 1.75 – | 2.00 |
| Sodium sulphide, fused, 60-62% drums | lb. | .03½ – | .03½ |
| Sodium sulphite, crys., bbl | lb. | .02½ – | .03 |
| Strontium nitrate, powd., bbl | lb. | .09½ – | .10 |
| Sulphur chloride, yel drums | lb. | .04 – | .05 |
| Sulphur, crude | ton | 18.00 – | 20.00 |
| At mine, bulk | ton | 16.00 – | 18.00 |
| Sulphur, flour, bag | 100 lb. | 2.25 – | 2.35 |
| Sulphur, roll, bag | 100 lb. | 2.00 – | 2.10 |
| Sulphur dioxide, liquid, cyl | lb. | .08 – | .08 |
| Tin bichloride, bbl | lb. | .12½ – | |
| Tin oxide, bbl | lb. | .48 – | |
| Tin crystals, bbl | lb. | .33 – | |
| Zinc carbonate, bags | lb. | .12 – | .14 |
| Zinc chloride, gran, bbl | lb. | .06 – | .07½ |
| Zinc cyanide, drums | lb. | .36½ – | .37 |
| Zinc dust, bbl | lb. | .08 – | .08½ |
| Zinc oxide, lead free, bag | lb. | .07½ – | |
| 5% lead sulphate, bags | lb. | .06½ – | |
| 10 to 35% lead sulphate, bags | lb. | .06½ – | |
| French, red seal, bags | lb. | .09½ – | |
| French, green seal, bags | lb. | .10½ – | |
| French, white seal, bbl | lb. | .11½ – | |
| Zinc sulphate, bbl | 100 lb. | 3.00 – | 3.25 |

## Coal-Tar Products

| | | | |
|---|---|---|---|
| Alpha-naphthol, crude, bbl | lb. | $0.60 – | $0.65 |
| Alpha-naphthol, ref., bbl | lb. | .65 – | .75 |
| Alpha-naphthylamine, bbl | lb. | .35 – | .36 |
| Aniline oil, drums | lb. | .16 – | .16½ |
| Aniline salt, bbl | lb. | .22 – | .23 |
| Anthracene, 80%, drums | lb. | .70 – | .75 |
| Anthraquinone, 25%, paste, drums | lb. | .75 – | .80 |
| Benzaldehyde U.S.P., carboys | lb. | 1.50 – | |
| f.f.e. drums | lb. | 1.60 – | |
| tech, drums | lb. | 68 – | .72 |
| Benzene, pure, water-white, tanks, works | gal. | .25 – | |
| Benzene, 90%, tanks, works | gal. | .23 – | |
| Benzidine base, bbl | lb. | .80 – | .82 |
| Benzidine sulphate, bbl | lb. | .70 – | .72 |
| Benzoic acid, U.S.P., kegs | lb. | .75 – | .85 |
| Benzoate of soda, U.S.P., bbl | lb. | .65 – | .70 |
| Benzyl chloride, 95-97%, ref. carboys | lb. | .35 – | |
| Benzyl chloride, tech., drums | lb. | .25 – | |
| Beta-naphthol, tech., bbl | lb. | .24 – | .25 |
| Beta-naphthylamine, tech | lb. | .65 – | .70 |
| Cresol, U.S.P., drums | lb. | .22 – | .26 |
| Ortho-cresol, drums | lb. | .28 – | .32 |
| Cresylic acid, 97%, works drums | gal. | .63 – | .67 |
| 95-97%, drums, works | gal. | .58 – | .61 |
| Dichlorbenzene, drums | lb. | .07 – | .08 |
| Diethylaniline, drums | lb. | .53 – | .58 |
| Dimethylaniline, drums | lb. | .36 – | .38 |
| Dinitrobenzene, bbl | lb. | .15 – | .17 |
| Dinitrochlorbenzene, bbl | lb. | .21 – | .22 |
| Dinitronaphthalen, bbl | lb. | .30 – | .32 |
| Dinitrophenol, bbl | lb. | .35 – | .40 |
| Dinitrotoluen, bbl | lb. | .18 – | .20 |
| Dip oil, 25%, drums | gal. | .26 – | .28 |
| Diphenylamine, bbl | lb. | .48 – | .50 |
| H-acid, bbl | lb. | .72 – | .75 |
| Meta-phenylenediamine, bbl | lb. | .95 – | 1.00 |
| Michlers ketone, bbl | lb. | 3.00 – | 3.25 |
| Monochlorbenzene, drums | lb. | .08 – | .10 |
| Monoethylaniline, drums | lb. | 1.20 – | 1.30 |
| Naphthalene, flake, bbl | lb. | .04½ – | .05½ |
| Naphthalene, balls, bbl | lb. | .05½ – | .05½ |
| Naphthionate of soda, bbl | lb. | .60 – | .65 |
| Naphthionic acid, crude, bbl | lb. | .60 – | .62 |
| Nitrobenzene, drums | lb. | .09 – | .09½ |
| Nitro-naphthalene, bbl | lb. | .25 – | .30 |
| Nitro-toluene, drums | lb. | .13½ – | .14 |
| N-W acid, bbl | lb. | 1.00 – | 1.05 |
| Ortho-amidophenol, kegs | lb. | 2.40 – | 2.50 |
| Ortho-dichlorbenzene, drums | lb. | .12 – | .13 |
| Ortho-nitrophenol, bbl | lb. | .95 – | 1.00 |
| Ortho-nitrotoluene, drums | lb. | .11 – | .12 |
| Ortho-toluidine, bbl | lb. | .12 – | .13 |
| Para-aminophenol, base, kegs | lb. | 1.20 – | 1.25 |
| Para-aminophenol, HCl, kegs | lb. | 1.30 – | 1.40 |
| Para-dichlorbenzene, bbl | lb. | .17 – | .20 |
| Paranitraniline, bbl | lb. | .68 – | .70 |
| Para-nitrotoluene, bbl | lb. | .52 – | .56 |
| Para-phenylenediamine, bbl | lb. | 1.35 – | 1.45 |
| Para-toluidine, bbl | lb. | .72 – | .80 |
| Phthalic anhydride, bbl | lb. | .36 – | .34 |
| Phenol, U.S.P., dr | lb. | .25 – | .27 |
| Picric acid, bbl | lb. | .20 – | .22 |
| Pitch, tanks, works | ton | 25.00 – | 30.00 |
| Pyridine, imp., drums | gal. | 3.75 – | 4.00 |
| Resorcinol, tech., kegs | lb. | 1.30 – | 1.40 |

| | | | |
|---|---|---|---|
| Resorcinol, pure, kegs | lb. | $2.00 - | $2.25 |
| R-salt, bbl | lb. | .50 - | .55 |
| Salicylic acid, tech., bbl | lb. | .32 - | .33 |
| Salicylic acid, U.SP., bbl | lb. | .35 - | |
| Solvent naphtha, water-white, tanks | gal. | .25 - | |
| Crude, tanks | gal. | .22 - | |
| Sulphanilic acid, crude, bbl | lb. | .16 - | .18 |
| Tolidine, bbl | lb. | 1.00 - | 1.05 |
| Toluidine, mixed, kegs | lb. | .30 - | .55 |
| Toluene, tank cars, works | gal. | .26 - | |
| Toluene, drums, works | gal. | .30 - | |
| Xylidine, drums | lb. | .45 - | .48 |
| Xylene, 5 deg.-tanks | gal. | .40 - | |
| Xylene, com., tanks | gal. | .28 - | |

## Naval Stores

| | | | |
|---|---|---|---|
| Rosin B-D, bbl | 280 lb. | $5.50 - | $5.55 |
| Rosin E-I, bbl | 280 lb. | 5.65 - | 5.70 |
| Rosin K-N, bbl | 280 lb. | 5.90 - | 6.10 |
| Rosin W.G.-W.W., bbl | 280 lb. | 7.00 - | 7.60 |
| Wood rosin, bbl | 280 lb. | 5.40 - | 5.50 |
| Turpentine, spirits of, bbl | gal. | .83 - | .84 |
| Wood, steam dist., bbl | gal. | .72½ - | .73 |
| Wood, dest. dist., bbl | gal. | .54 - | .55 |
| Pine tar pitch, bbl | 200 lb. | 5.50 - | |
| Tar, kiln burned, bbl | 500 lb. | 10.50 - | |
| Retort tar, bbl | 500 lb. | 10.50 - | |
| Rosin oil, first run, bbl | gal. | .38 - | |
| Rosin oil, second run, bbl | gal. | .43 - | |
| Rosin oil, third run, bbl | gal. | .48 - | |
| Pine oil, steam dist | gal. | .60 - | |
| Pine tar oil, com'l | gal. | .30 - | |

## Animal Oils and Fats

| | | | |
|---|---|---|---|
| Degras, bbl | lb. | $0.03½ - | $0.05½ |
| Grease, yellow, loose | lb. | .06½ - | .07 |
| Lard oil, Extra No. 1, bbl | gal. | .85 - | |
| Lard compound, bbl | lb. | .12½ - | .13 |
| Neatsfoot 1 20 deg. bbl | gal. | 1.26 - | |
| No. 1, bbl | gal. | .86 - | .88 |
| Oleo Stearine | lb. | .12½ | |
| Oleo oil, No. 1, bbl | lb. | .13½ | |
| Red oil, distilled, d.p. bbl | lb. | .08½ - | .09 |
| Saponified, bbl | lb. | .08½ - | .09 |
| Tallow, extra, loose works | lb. | .07½ - | |
| Tallow oil, acidless, bbl | gal. | .82 - | |

## Vegetable Oils

| | | | |
|---|---|---|---|
| Castor oil, No. 3, bbl | lb. | $0.15½ - | |
| Castor oil, No. 1, bbl | lb. | .16 - | |
| Chinawood oil, bbl | lb. | .14 - | .14½ |
| Coconut oil, Ceylon, bbl | lb. | .09½ - | .09½ |
| Ceylon, tanks, N.Y | lb. | .08½ - | |
| Coconut oil, Cochin, bbl | lb. | .10 - | .10½ |
| Corn oil, crude, bbl | lb. | .12 - | .12½ |
| Crude, tanks, (f.o.b. mill) | lb. | .09½ - | |
| Cottonseed oil, crude (f.o.b. mill), tanks | lb. | .09½ - | .09½ |
| Summer yellow, bbl | lb. | .11½ - | .12 |
| Winter yellow, bbl | lb. | .12½ - | .12½ |
| Linseed oil, raw, car lots, bbl | gal. | .96 - | |
| Raw, tank cars (dom.) | gal. | .90 - | |
| Boiled, cars, bbl. (dom.) | gal. | .98 - | |
| Olive oil, denatured, bbl | gal. | 1.15 - | 1.20 |
| Sulphur, (foots) bbl | lb. | .09½ - | .09½ |
| Palm, Lagos, casks | lb. | .07½ - | |
| Niger, casks | lb. | .07½ - | |
| Palm kernel, bbl | lb. | .09½ - | |
| Peanut oil, crude, tanks (mill) | lb. | .11 - | |
| Peanut oil, refined, bbl | lb. | .14½ - | .15 |
| Perilla, bbl | lb. | .14 - | .14½ |
| Rapeseed oil, refined, bbl | gal. | .78 - | .80 |
| Sesame, bbl | lb. | .11½ - | .11½ |
| Soya bean (Manchurian), bbl | lb. | .11½ - | .11½ |
| Tank, f.o.b. Pacific coast | lb. | .10½ - | |
| Tank, (f.o.b. N.Y.) | lb. | .10½ - | |

## Fish Oils

| | | | |
|---|---|---|---|
| Cod, Newfoundland, bbl | gal. | $0.60 - | $0.62 |
| Menhaden, light pressed, bbl | gal. | .56 - | |
| White bleached, bbl | gal. | .58 - | |
| Blown, bbl | gal. | .62 - | |
| Crude, tanks (f.o.b. factory) | gal. | .37½ - | |
| Whale No. 1 crude, tanks, coast | lb. | | .76 |
| Winter, natural, bbl | gal. | .75 - | .76 |
| Winter, bleached, bbl | gal. | .78 - | .79 |

## Oil Cake and Meal

| | | | |
|---|---|---|---|
| Coconut cake, bags | ton | $30.00 - | 32.00 |
| Cottonseed meal, f.o.b. mills | ton | 39.00 - | 40.00 |
| Linseed cake, bags | ton | 38.00 - | 39.00 |
| Linseed meal, bags, spot | ton | 42.00 - | 43.00 |

## Dye & Tanning Materials

| | | | |
|---|---|---|---|
| Albumen, blood, bbl | lb. | $0.50 - | $0.55 |
| Albumen, egg, tech, kegs | lb. | .95½ - | .97 |
| Cochineal, bags | lb. | .33 - | .35 |
| Cutch, Borneo, bales | lb. | .04½ - | .04½ |
| Cutch, Rangoon, bales | lb. | .13½ - | .14½ |
| Dextrine, corn, bags | 100 lb. | 4.12 - | 4.39 |
| Dextrine, gum, bags | 100 lb. | 4.42 - | 4.69 |
| Divi-divi, bags | ton | 40.00 - | 42.00 |
| Fustic, sticks | ton | 30.00 - | 35.00 |
| Fustic, chips, bags | lb. | .04 - | .05 |
| Gambier, com., bags | lb. | .13 - | .13½ |
| Logwood, sticks | ton | 25.00 - | 26.00 |
| Logwood, chips, bags | lb. | .02½ - | .03 |
| Sumac, leaves, Sicily, bags | ton | 165.00 - | 170.00 |
| Sumac, ground, bags | ton | 155.00 - | 160.00 |
| Sumac, domestic, bags | ton | 50.00 - | 55.00 |
| Starch, corn, bags | 100 lb. | 3.47 - | 3.74 |
| Tapioca flour, bags | lb. | .04½ - | .06 |

## Extracts

| | | | |
|---|---|---|---|
| Archil, conc., bbl | lb. | $0.16 - | $0.19 |
| Chestnut, 25% tannin, tanks | lb. | .01½ - | .02 |
| Divi-divi, 25% tannin, bbl | lb. | .04½ - | .05½ |
| Fustic, crystals, bbl | lb. | .20 - | .22 |
| Fustic, liquid, 42°, bbl | lb. | .08 - | .09 |
| Gambier, liq., 25% tannin, bbl | lb. | .11 - | .11½ |
| Hematine crys., bbl | lb. | .14 - | .18 |
| Hemlock, 25% tannin, bbl | lb. | .03½ - | .04 |
| Hypernic, solid, drums | lb. | .22 - | .24 |
| Hypernic, liquid, 51°, bbl | lb. | .12 - | .13 |
| Logwood, crys., bbl | lb. | .14 - | .15 |
| Logwood, liq., 51°, bbl | lb. | .07½ - | .08½ |
| Osage Orange, 51° liquid, bbl | lb. | .07 - | .08 |
| Osage Orange, powder, bg | lb. | .14 - | .15 |
| Quebracho, solid, 65% tannin, bbl | lb. | .04½ - | .04½ |
| Sumac, dom., 51°, bbl | lb. | .06½ - | .07 |

## Dry Colors

| | | | |
|---|---|---|---|
| Blacks–Carbongas, bags, f.o.b. works, contract | lb. | $0.09 - | $0.11 |
| spot, cases | lb. | .12 - | .16 |
| Lampblack, bbl | lb. | .12 - | .40 |
| Mineral, bulk | ton | 35.00 - | 45.00 |
| Blues–Bronze, bbl | lb. | .38 - | .40 |
| Prussian, bbl | lb. | .38 - | .40 |
| Ultramarine, bbl | lb. | .08 - | .35 |
| Browns, Sienna, Ital., bbl | lb. | .06 - | .14 |
| Sienna, Domestic, bbl | lb. | .03½ - | .04 |
| Umber, Turkey, bbl | lb. | .04 - | .04½ |
| Greens–Chrome, C.P. Light, bbl | lb. | .28 - | .30 |
| Chrome, commercial, bbl | lb. | .11½ - | .12 |
| Paris, bulk | lb. | .24 - | .26 |
| Reds, Carmine No. 40, tins | lb. | 4.25 - | 4.50 |
| Iron oxide red, casks | lb. | .08 - | .12 |
| Para toner, kegs | lb. | .95 - | 1.00 |
| Vermilion, English, bbl | lb. | 1.25 - | 1.30 |
| Yellow, Chrome, C.P. bbls | lb. | .17 - | .17½ |
| Ocher, French, casks | lb. | .02½ - | .03 |

## Waxes

| | | | |
|---|---|---|---|
| Bayberry, bbl | lb. | $0.21 - | $0.21½ |
| Beeswax, crude, Afr. bg | lb. | .25 - | .26 |
| Beeswax, refined, light, bags | lb. | .32 - | .34 |
| Beeswax, pure white, cases | lb. | .40 - | .41 |
| Candellila, bags | lb. | .23 - | .23½ |
| Carnauba, No. 1, bags | lb. | .39 - | .40 |
| No. 2, North Country, bags | lb. | .28 - | .29 |
| No. 3, North Country, bags | lb. | .21 - | .22 |
| Japan, cases | lb. | .20 - | .21 |
| Montan, crude, bags | lb. | .05½ - | .06 |
| Paraffine, crude, match, 105-110 m.p., bbl | lb. | .05½ - | |
| Crude, scale 124-126 m.p. bags | lb. | .04½ - | |
| Ref., 118-120 m.p., bags | lb. | .04½ - | |
| Ref., 123-125 m.p., bags | lb. | .05½ - | |
| Ref., 128-130 m.p., bags | lb. | .05½ - | .05½ |
| Ref., 133-135 m.p., bags | lb. | .06½ - | .07 |
| Ref., 135-137 m.p., bags | lb. | .07½ - | .07½ |
| Stearic acid, sgle pressed, bags | lb. | .10½ - | |
| Double pressed, bags | lb. | .11 - | |
| Triple pressed, bags | lb. | .12½ - | |

## Fertilizers

| | | | |
|---|---|---|---|
| Acid phosphate, 16%, bulk, works | ton | $7.50 - | $7.75 |
| Ammonium sulphate, bulk f.o.b. works | 100 lb. | 2.50 - | |
| Blood, dried, bulk | unit | 4.10 - | 4.15 |
| Bone, raw, 3 and 50, ground | ton | 26.00 - | 28.00 |
| Fish scrap, dom., dried, wks | unit | | |
| Nitrate of soda, bags | 100 lb. | 2.60 - | |
| Tankage, high grade, f.o.b. Chicago | unit | 2.50 - | |
| Phosphate rock, f.o.b. mines Florida pebble, 68-72% | ton | 3.25 - | 3.70 |
| Tennessee, 75% | ton | 6.75 - | 7.00 |
| Potassium muriate, 80%, bags | ton | 34.55 - | |
| Potassium sulphate, bags basis 90% | ton | 45.85 - | |
| Double manure salt | ton | 26.35 - | |
| Kainit | ton | 7.22 - | |

## Crude Rubber

| | | | |
|---|---|---|---|
| Para–Upriver fine | lb. | $0.20½ - | |
| Upriver coarse | lb. | .15 - | |
| Upriver caucho ball | lb. | .15 - | |
| Plantation–First latex crepe | lb. | .21½ - | |
| Ribbed smoked sheets | lb. | .20½ - | |
| Amber crepe No. 1 | lb. | .19½ - | |

## Gums

| | | | |
|---|---|---|---|
| Copal, Congo, amber, bags | lb. | $0.09 - | $0.14 |
| East Indian, bold, bags | lb. | .13 - | .14 |
| Manila, pale, bags | lb. | .18 - | .19 |
| Pontinak, No. 1 bags | lb. | .19 - | .20 |
| Damar, Batavia, cases | lb. | .23 - | .23½ |
| Singapore, No. 1, cases | lb. | .27 - | .27½ |
| Singapore, No. 2, cases | lb. | .18½ - | .19 |
| Kauri, No. 1, cases | lb. | .58 - | .64 |
| Ordinary chips, cases | lb. | .21 - | .22 |
| Manjak, Barbados, bags | lb. | .06 - | .09 |

## Shellac

| | | | |
|---|---|---|---|
| Shellac, orange fine, bags | lb. | $0.55 - | $0.56 |
| Orange superfine, bags | lb. | .57 - | .58 |
| A. C. garnet, bags | lb. | .52 - | |
| Bleached, bonedry | lb. | .63 - | .64 |
| Bleached, fresh | lb. | .52 - | .53 |
| T. N., bags | lb. | .53 - | .54 |

## Miscellaneous Materials

| | | | |
|---|---|---|---|
| Asbestos, crude No. 1, f.o.b., Quebec | sh. ton | $300.00 - | $400.00 |
| Asbestos, shingle, f.o.b., Quebec | sh. ton | 50.00 - | 70.00 |
| Asbestos, cement, f.o.b., Quebec | sh. ton | 20.00 - | 25.00 |
| Barytes, grd., white, f.o.b. mills, bbl | net ton | 16.00 - | 17.00 |
| Barytes, grd., off-color, f.o.b. Balt | net ton | 13.00 - | 14.00 |
| Barytes, floated, f.o.b. St. Louis, bbl | net ton | 23.00 - | 24.00 |
| Barytes, crude f.o.b. mines, bulk | net ton | 8.00 - | 9.00 |
| Casein, bbl., tech | lb. | .10½ - | .12 |
| China clay (kaolin) crude, No. 1, f.o.b. Ga | net ton | 7.00 - | 8.00 |
| Washed, f.o.b. Ga | net ton | 8.50 - | 9.00 |
| Powd., f.o.b. Ga | net ton | 14.00 - | 20.00 |
| Crude f.o.b. Va | net ton | 6.00 - | 8.00 |
| Ground, f.o.b. Va | net ton | 13.00 - | 19.00 |
| Imp., lump, bulk | net ton | 15.00 - | 20.00 |
| Imp., powd | net ton | 45.00 - | 50.00 |
| Feldspar, No. 1 f.o.b. N.C | long ton | 7.00 - | 7.50 |
| No. 2 f.o.b. N.C | long ton | 4.50 - | 5.00 |
| No. 1 gr'd. N. C | long ton | 15.32 - | 21.00 |
| No. 1 Canadian, f.o.b. mill, powd | long ton | 20.00 - | |
| Graphite, Ceylon, lump, first quality | lb. | .05½ - | .06 |
| Ceylon, chip, bbl | lb. | .04½ - | .05 |
| High grade amorphous crude | ton | 15.00 - | 35.00 |
| Gum arabic, amber, sorts, bags | lb. | .11½ - | .11½ |
| Gum tragacanth, sorts, bags | lb. | .50 - | .51 |
| No. 1, bags | lb. | 1.20 - | |
| Kieselguhr, f.o.b. Cal | ton | 40.00 - | 42.00 |
| F.o.b. N.Y | ton | 50.00 - | 55.00 |
| Magnesite, calcined, f.o.b. Cal. ton | ton | 35.00 - | 45.00 |
| Pumice stone, imp., casks | lb. | .03 - | .40 |
| Dom., lump, bbl | lb. | .06 - | .08 |
| Dom., ground, bbl | lb. | .03 - | .05 |
| Silica, glass sand, f.o.b. Ind | ton | 2.00 - | 2.50 |
| Silica, sand blast, f.o.b. Ind | ton | 2.25 - | 3.50 |
| Silica, amorphous, 200-mesh, f.o.b. Ill | ton | 20.00 - | |
| Silica, glass sand, f.o.b. Ill | ton | 2.00 - | 2.50 |
| Soapstone, coarse, f.o.b. Vt., bags | ton | 7.50 - | 8.00 |
| Talc, 200 mesh, f.o.b., Vt., bags, extra | ton | 10.50 - | |
| Talc, 200 mesh, f.o.b. Ga., bags | ton | 8.00 - | 10.00 |
| Talc, 325 mesh, f.o.b. New York, grade A bags | ton | 14.75 - | |

## Mineral Oils

### Crude, at Wells

| | | | |
|---|---|---|---|
| Pennsylvania | bbl. | $3.00 - | $3.25 |
| Corning | bbl. | 1.80 - | |
| Cabell | bbl. | 1.60 - | |
| Somerset | bbl. | 1.70 - | |
| Illinois | bbl. | 1.97 - | |
| Indiana | bbl. | 1.98 - | |
| Kansas and Okla. under 28 deg. | bbl. | .90 - | |
| California, 35 deg. and up | bbl. | 1.40 - | |

### Gasoline, Etc.

| | | | |
|---|---|---|---|
| Motor gasoline, steel bbls | gal. | $0.20 - | |
| Naphtha, V. M. & P. deod, steel bbls | gal. | .19 - | |
| Kerosene, ref. tank wagon | gal. | .14 - | |
| Bulk, W.W. delivered, N.Y. | gal. | .08 - | |
| Lubricating oils: | | | |
| Cylinder, Penn., filtered | gal. | .30 - | .35 |
| Bloomless, 30@31 grav. | gal. | .21 - | .22 |
| Paraffin, pale 885 vis | gal. | .16 - | .17 |
| Spindle, 200, pale | gal. | .22 - | |
| Petrolatum, amber, bbls | lb. | .04 - | .04½ |
| Paraffine wax (see waxes) | | | |

## Refractories

| | | | |
|---|---|---|---|
| Bauxite brick, 56% Al₂O₃, f.o.b. Pittsburgh | 1,000 | $140-$145 | |
| Chrome brick, f.o.b. Eastern shipping points | ton | 45-47 | |
| Chrome cement, 40-50% Cr₂O₃ | ton | 23-27 | |
| 40-45% Cr₂O₃, sacks, f.o.b. Eastern shipping points | ton | 23.00 | |
| Fireclay brick, 1st. quality, 9-in. shapes, f.o.b. Ky. wks | 1,000 | 42-45 | |
| 2nd. quality, 9-in. shapes, f.o.b. wks | 1,000 | 35-38 | |
| Magnesite brick, 9-in. straight (f.o.b. wks.) | ton | 65-68 | |
| 9-in. arches, wedges and keys | ton | 80-85 | |
| Scraps and splits | ton | 85 | |
| Silica brick, 9-in. sizes, f.o.b. Chicago district | 1,000 | 48-50 | |
| Silica brick, 9-in. sizes, f.o.b. Birmingham district | 1,000 | 48-50 | |
| F.o.b. Mt. Union, Pa. | 1,000 | 38-40 | |
| Silicon carbide refract. brick, 9-in. | 1,000 | 1,180.00 | |

## Ferro-Alloys

| | | | |
|---|---|---|---|
| Ferrotitanium, 15-18% f.o.b. Niagara Falls, N.Y. | ton | $200.00 - | |

Bauxite brick figures continued.

## Miscellaneous Materials (continued - Dry Colors Reds)

Reds, Carmine listing.

| Ferrochromium, per lb. of | | | |
|---|---|---|---|
| Cr, 1-2% C......... | lb. | $0 30 | ..... |
| 4-6% C........... | lb. | .11½- | ..... |
| Ferromanganese, 78-82% | | | |
| Mn, Atlantic seabd. | | | |
| duty paid....... | gr. ton | 107.50 - | .. |
| Spiegeleisen, 19-21% Mn.. | gr. ton | 35.00 - | 36.00 |
| Ferromolybd enum, 50-60% | | | |
| Mo, per lb. Mo ... | lb. | 2.00 - | 2.25 |
| Ferrosilicon, 10-12%..... | gr. ton | 39.50 - | 43.50 |
| 50%.............. | gr. ton | 75.00 - | ..... |
| Ferrotungsten, 70-80%, | | | |
| per lb. of W....... | | .90 - | .93 |
| Ferro-uranium, 35-50%, of | | | |
| U, per lb. of U...... | lb. | 4.50 - | ..... |
| Ferrovanadium, 30-40%, | | | |
| per lb. of V........ | lb. | 3.50 - | 4.00 |

## Ores and Semi-finished Products

| | | | |
|---|---|---|---|
| Bauxite, dom. crushed, dried, f.o.b. shipping points.............. | ton | $5.50 - | $8.75 |
| Chrome ore Calif. concentrates, 50% min. Cr₂O₃ | ton | 22.00 - | ..... |
| C.i.f. Atlantic seaboard... | ton | 19.00 - | 23.00 |
| Coke, fdry., f.o.b. ovens.... | ton | 4.50 - | 5.00 |
| Coke, furnace, f.o.b. ovens.... | ton | 3.00 - | 3.25 |
| Fluorspar, gravel, f.o.b. mines, Illinois........ | ton | 23.50 - | ..... |
| Ilmenite, 52% TiO₂ Va.... | lb. | .01½- | ..... |
| Manganese ore, 50% Mn, c.i.f. Atlantic seaport.. | unit | .42 - | .46 |
| Manganese ore, chemical (MnO₂)............ | ton | 75.00 - | 80.00 |
| Molybdenite, 85% MoS₂, per lb. MoS₂, N. Y.... | lb. | .80 - | ..... |
| Monazite, per unit of ThO₂, c.i.f., Atl. seaport..... | lb. | .06 - | .08 |
| Pyrites, Span., fines, c.i.f. Atl. seaport.......... | unit | .11½- | .12 |
| Pyrites, Span., furnace size, c.i.f. Atl. seaport...... | unit | .11½- | .12 |
| Pyrites, dom. fines, f.o.b. mines, Ga........... | unit | .12 - | ..... |
| Rutile, 94@96% TiO₂..... | lb. | .12 - | .15 |
| Tungsten, scheelite, 60% WO₃ and over........ | unit | 9.25 - | ..... |
| Tungsten, wolframite, 60% WO₃............ | unit | 9.00 - | 9.25 |
| Uranium ore (carnotite) per lb. of U₃O₈....... | lb. | 3.50 - | 3.75 |
| Uranium oxide, 96% per lb. U₃O₈............ | lb. | 12.25 - | 2.50 |
| Vanadium pent oxide, 99%... | lb. | 2.00 - | 14.00 |
| Vanadium ore, per lb. V₂O₅.. | lb. | 1.00 - | 1.25 |
| Zircon, 99%............. | lb. | .06 - | .07 |

## Non-Ferrous Metals

| | | | |
|---|---|---|---|
| Copper, electrolytic......... | lb. | $0.12½- | $0.12½ |
| Aluminum, 98 to 99%....... | lb. | .27 - | .28 |
| Antimony, wholesale, Chinese and Japanese........... | lb. | .08½- | .08¾ |
| Nickel, 99%............. | lb. | .27 - | .30 |
| Monel metal, sheet and blocks | lb. | .32 | |
| Tin, 5-ton lots, Straits....... | lb. | .43½ | |
| Lead, New York, spot....... | | .07 | |
| Lead, E. St. Louis, spot...... | lb. | .0665 | |
| Zinc, spot, New York...... | lb. | .0615 | |
| Zinc, spot, E. St. Louis...... | lb. | .0580 | |
| Silver (commercial)........... | oz. | .66⅞ | |
| Cadmium................ | lb. | .60 | |
| Bismuth (500 lb. lots)....... | lb. | 2.35-2.40 | |
| Cobalt................ | lb. | 2.50-3.00 | |
| Magnesium, ingots, 99%..... | lb. | .90-.95 | |
| Platinum, refined............ | oz. | 116.00 | |
| Iridium ............... | oz. | 260.00-270.00 | |
| Palladium, refined........... | oz. | 78.00-83.00 | |
| Mercury.............. | 75 lb. | 73.00-74.00 | |
| Tungsten powder.......... | lb. | .95-1.00 | |

## Finished Metal Products

| | Warehouse Price Cents per Lb. |
|---|---|
| Copper sheets, hot rolled............. | 18.25 |
| Copper bottoms.................... | 28.00 |
| Copper rods...................... | 18.75 |
| High brass wire.................... | 16.75 |
| High brass rods................... | 14.00 |
| Low brass wire.................... | 18.50 |
| Low brass rods.................... | 19.50 |
| Brazed bronze tubing................ | 23.75 |
| Seamless copper tubing.............. | 21.75 |
| Seamless high brass tubing........... | 20.50 |

**OLD METALS**—The following are the dealers purchasing prices in cents per pound

| | | |
|---|---|---|
| Copper, heavy and crucible........ | 9.50 @ | 9.75 |
| Copper, heavy and wire........... | 9.25 @ | 9.37½ |
| Copper, light and bottoms......... | 7.50 @ | 7.75 |
| Lead, heavy..................... | 5.50 @ | 5.75 |
| Lead, tea....................... | 3.50 @ | 3.62½ |
| Brass, heavy .................... | 4.75 @ | 5.00 |
| Brass, light .................... | 4.00 @ | 4.25 |
| No. 1 yellow brass turnings......... | 6.00 @ | 6.25 |
| Zinc scrap...................... | 3.37½@ | 3.50 |

## Structural Material

The following base prices per 100 lb. are for structural shapes 3 in. by ¼ in. and larger, and plates ¼ in. and heavier, from jobbers' warehouses in the cities named:

| | New York | Chicago |
|---|---|---|
| Structural shapes............. | $3.44 | $3.44 |
| Soft steel bars............... | 3.34 | 3.34 |
| Soft steel bar shapes.......... | 3.54 | 3.54 |
| Soft steel bands............. | 4.09 | 4.09 |
| Plates, ⅛ to 1 in. thick.. | 3.44 | 3.44 |

# Industrial

## Financial, Construction and Manufacturing News

## Construction and Operation

### Alabama

BESSEMER—The Hercules Powder Co., Wilmington, Del., has construction in progress on a new plant at McAdory, near Bessemer, comprising a number of units, estimated to cost in excess of $200,000, with equipment. It will be used for explosive production for mine service, and is expected to be ready for occupancy in the near future.

### Arizona

GLOBE—A. C. Belcher, Globe, operating a local gold mine, has preliminary plans for the construction of a mill at the property and will break ground at an early date.

OATMAN—The Gold Dust Mining Co. has work in progress on changes in its amalgamating plant, remodeling the structure for a cyanide mill, the ores not being suitable for amalgamation. Additional equipment will be installed. It is purposed to have the structure ready for service in the near future. Charles Waters has recently taken over the management of the property.

### California

BURLINGAME—The Keaton Tire & Rubber Co. has negotiations in progress for a local site for a new plant for the manufacture of automobile tires and other rubber products, estimated to cost about $200,000, including equipment. It is expected to have plans drawn at an early date.

### Connecticut

NEW HAVEN—Fire, June 28, destroyed a building at the plant of the Baumann Rubber Co., Congress Ave., with loss reported at $25,000. It is planned to rebuild.

### Florida

MIAMI—The Airkool Spark Plug Co. has plans for the erection of a new local plant on 29th St., near 2nd Ave., 100x145 ft., for the manufacture of porcelain spark plugs. It is estimated to cost approximately $125,000, with equipment, and will have facilities for the employment of about 125 operatives, running on a basis of 1,000 plugs per day. The plan is now scheduled to be ready for service in September. Kiehnel & Elliott, Miami, are architects. J. B. Harper is president, and P. S. Campbell secretary and treasurer.

JACKSONVILLE—The Globe Charcoal Co., Norwood, near Jacksonville, is reported to be planning for the rebuilding of the portion of its plant recently destroyed by fire with loss estimated at $30,000, including equipment.

### Illinois

HARVEY—The American Stove Enameling Co. will build a new local plant, for which a general contract recently has been let to the Kenwood Bridge Co. It is estimated to cost in excess of $40,000, including equipment.

LINCOLN—Fire, June 28, destroyed a portion of the local plant of the Whaleback Oil & Production Co., with loss reported at more than $35,000, with equipment.

### Indiana

HARTFORD CITY—The Fort Wayne Corrugated Paper Co., Murray and Barr Sts., Fort Wayne, Ind., has asked bids on a general contract for the erection of a new plant at Hartford City, to be 1- and 2-story, 180x350 ft., estimated to cost $250,000, including machinery.

EVANSVILLE—The Mead-Johnson Co., West Ohio St., manufacturer of food products, has awarded a general contract to the M. J. Hoffman Co., Furniture Bldg., for the construction of a new 2-story and basement laboratory, 45x115 ft., estimated to cost $75,000, including equipment. A list of apparatus to be installed will be arranged at an early date. Shopbell, Fowler & Thole, Furniture Bldg., are architects.

INDIANAPOLIS—The National Malleable Castings Co., 546 North Holmes Ave., is taking bids on a general contract for the erection of a 1-story addition to its foundry, to be 93x630 ft., located at West Michigan and Holmes Ave., estimated to cost $100,000.

### Kansas

WICHITA—The Sterling Refinery plans for the rebuilding of the portion of its oil storage and distributing plant at 25th and Santa Fe Sts., recently destroyed by fire with loss estimated at $35,000, including equipment.

### Maryland

WALDORF (Charles County)—The Southern Maryland Fertilizer Works, Inc., recently organized with a capital of $550,000, is said to have plans under consideration for the establishment of a local fertilizer manufacturing and mixing plant, with estimated cost placed in excess of $85,000. Albert J. Boyle, Garden Apartments, Baltimore, is one of the heads of the company.

BALTIMORE—The Maryland Glass Corp., Mt. Winans, Baltimore, has awarded a general contract to the Consolidated Engineering Co., Calvert Bldg., for the construction of a 2-story addition at Linden and Ontario Sts., on which work will proceed at once.

### Michigan

DETROIT—The Howard Flint Ink Co., 1424 Sherman St., has taken bids on a general contract and will soon make award for the construction of a 2-story and basement plant, 100x230 ft., on Scotten Ave., for which plans have been drawn by Weston & Ellington, Stroh Bldg., architects. It is estimated to cost in excess of $30,000. Howard H. Flint is head.

DETROIT—The Peerless Portland Cement Co., First National Bank Bldg., has awarded a general contract to H. L. Vanderhorst, Main and Thompson Sts., Kalamazoo, for the erection of the first unit of its proposed new mill on West Jefferson Ave., comprising a number of buildings, estimated to cost $3,000,000, with machinery. The company is now operating a plant at Union City, Mich., which will be maintained in service. Albert Kahn, Marquette Bldg., Detroit, is architect. A. F. Miller is company engineer.

DETROIT—The Higgins Brass & Mfg. Co. will begin the erection of a new plant on Dequindre St., between Davison and Carpenter Sts., to be 1-story, 80x160 ft., estimated to cost $25,000.

LANSING—The Lansing Fuel & Gas Co. has plans under consideration for extensions in its central gas generating works, with the installation of additional equipment for considerable increase in output.

WYANDOTTE—The Detroit Soda Products Co., 9077 West Jefferson Ave., Detroit, manufacturer of washing soda, etc., is planning for the early removal to its new plant on George St., Wyandotte, where the capacity will be considerably advanced.

### Minnesota

MARSHALL—The Common Council has tentative plans under advisement for the construction of a new filtration plant at the municipal waterworks. It is purposed to arrange a bond issue at an early date.

THIEF RIVER FALLS—The Peat Fuel Dehydration Co. is planning for the erection of a new plant for dehydrating service, on local site. A list of equipment to be installed will soon be arranged.

### Missouri

KANSAS CITY—The Western Boiler Compound Co., 306 Delaware Ave., has asked bids for the erection of a new 1½-story plant at 713-15 Washington St., to be 50x64 ft., estimated to cost about $18,000. George W. Swehla, Westport Bank Bldg., is architect. M. L. Frisher heads the company.

### New Jersey

EDGEWATER—Fire, June 30, destroyed a building at the local plant of Spencer Kellogg & Sons, Inc., manufacturer of linseed oil products, etc., with loss reported at

$30,000. It is planned to rebuild. Headquarters of the company are at 98 Delaware St., Buffalo, N. Y.

## New York

SOLVAY—The Iroquois China Co., Syracuse, has awarded a general contract to Dawson Brothers, Union Bldg., Syracuse, for the rebuilding of the portion of its 2-story pottery at Solvay, near Syracuse, recently destroyed by fire. The work will cost about $45,000.

BROOKLYN—E. R. Squibb & Sons, 80 Beekman St., New York, manufacturers of chemicals, have commenced the erection of the proposed addition to their plant and laboratories in the Columbia Heights section, to occupy the entire block between Vine and Doughty Sts. It will be 13-story, estimated to cost $750,000, with equipment. The Turner Construction Co., 242 Madison Ave., New York, has the general contract. Russell G. and Walter M. Cory, 30 Church St., New York, are architects and engineers.

TOTTENVILLE, S. I.—The Tottenville Copper Co. has filed plans for the erection of a 2-story addition to its plant, 50x80 ft., to cost about $25,000, and will equip a portion of the structure for furnace service. It will be located on Bethel Ave. A general building contract has been awarded to James F. McDermott, Stapleton, S. I.

## North Carolina

CHARLOTTE—The Carolina Standard Gas Products Co., Charlotte, has plans for the erection of a new local plant for the production of commercial oxygen and kindred products, estimated to cost $150,000, including equipment. Work will begin at an early date. Phillip W. Wilcox, 256 Clifton Ave., Atlanta, Ga., is president.

RALEIGH—The Capudine Chemical Co., West Martin St., plans for the rebuilding of the portion of its plant on West Martin St., recently destroyed by fire with loss estimated at $12,000.

CANTON—The Champion Fibre Co., will proceed with the erection of a new 2-story and basement addition to its plant, 132x200 ft., for which a general contract recently was awarded to the Aberthaw Construction Co., Boston, Mass. It will be used for the manufacture of bond and kraft papers, designed for a finishing capacity of 100 tons per day, with estimated cost placed at $650,000, with equipment. Reuben Robertson is president.

## North Dakota

FARGO—The City Council has plans for extensions and improvements in the filtration plant at the municipal waterworks, estimated to cost $70,000. Bids will be asked. R. T. Jacobson is city engineer.

## Ohio

ZANESVILLE—The Mosaic Tile Co. has secured permission from the city for the vacating of Dryden Rd., and will proceed at once with the erection of its proposed new plant in this section, with initial unit estimated to cost $200,000, including equipment.

TOLEDO—The Libbey-Owens Sheet Glass Co., Nicholas Bldg., will soon begin the erection of a new grinding and polishing plant at its local works, with reported cost placed in excess of $150,000, including machinery. It is expected to have the structure ready for occupancy early in the fall. Lockwood, Greene & Co., Hanna Bldg., Cleveland, O., are architects and engineers.

NEW PHILADELPHIA—The Houck Rubber Co., Akron, O., has acquired the local plant of the Tuscora Rubber Co., bankrupt, and will take immediate possession. The new owner will make improvements, including equipment betterments, and expects to begin production at an early date.

## Oregon

COQUILLE—The Alpine Paper Co., recently formed by local interests, is perfecting plans for the erection of a new pulp and paper mill on site now being secured. It will cost about $400,000, with machinery, and will give employment to more than 100 operatives. William Alpine, Coquille, is head.

## Tennessee

SPARTA—The Sun Paint Pigment Co., Knoxville, lately chartered with a capital of $150,000, is said to have plans under way for the erection of a new plant on site selected at Sparta, for the manufacture of paint pigments and affiliated products. It will cost close to $50,000. R. E. L.

Smith and Oliver W. Hill, 520 West Church St.

## Texas

BRECKENRIDGE—J. M. Huber, Monroe, La., and associates are said to have preliminary plans under way for the erection of a carbon black plant on local site, consisting of a number of buildings, estimated to cost close to $200,000, including equipment.

## Virginia

NORFOLK—The Virginia Portland Cement Co., National Bank of Commerce Bldg., is perfecting plans for the construction of a new local mill, consisting of a number of buildings, with power house, estimated to cost in excess of $1,000,000. It is said that work will be started before the close of the month. The company has a tract of property for raw material supply in the immediate vicinity, on the James River, and will also install equipment here. The International Cement Corp., 342 Madison Ave., New York, operates the company.

## West Virginia

CLARKSBURG—The Clarksburg Glass Co. has work in progress on expansion of its local plant, with installation of new sheet glass drawing machines and accessory equipment, and purposes to have the enlarged works ready for operation during August, with extensive increase in output.

## Wisconsin

STEVENS POINT—The Stevens Point Pulp & Paper Co. plans for the rebuilding of its chemical recovery works, recently destroyed by fire with loss estimated at close to $30,000, including equipment.

---

## New Companies

DETROIT FIBRE CO., Detroit, Mich.; fiber products; $50,000. Incorporators: F. W. Heller, F. L. Lane and J. R. Schantz, 2985 Iroquois Ave., Detroit. The last noted is representative.

MASTER LUBRICATOR, INC., Newark, N. J.; lubricating oils; $10,000. Incorporators: Milton Auffinger, Adolph and Carl Mass, 225 South 11th St., Newark. The last noted is representative.

NEUSHINE MFG. CO., Los Angeles, Calif.; polishes, etc.; $25,000. Incorporators: Mauro Herrera and Rudolph J. Arata. Representative: Grant Jackson, 1001 Great Republic Life Bldg., Los Angeles.

FLORIDA SMELTING CO., Miami, Fla., operate a metal smelting and refining plant; $25,000. F. W. Sheehan is president, and William W. Perry secretary and treasurer, both of Miami.

WASHINGTON CLAY PRODUCTS CO., Loughborough, Montgomery County, Md.; $10,000; vitrified brick, face brick and other burned clay products. Incorporators: Austin M. Knight, William E. Leidy and Clarence W. Clewes, all of Loughborough.

ARDMORE MFG. & SUPPLY CO., 3703 Wentworth Ave., Chicago, Ill.; rubber specialties, etc.; $5,000. Incorporators: Vincent and John L. Miller, and Guy L. Matthews.

LACQUER PRODUCTS CO., Providence, R. I.; lacquers and affiliated products; $50,000. Incorporators: Gilbreth Brown, Lincoln Vaughn and P. B. Deming, 80 Wheeler Ave., Providence.

CATAWBA CHEMICAL CO., Fort Mill, S. C.; chemicals and chemical byproducts; capital not stated. John Everett Jones is president, and Augustus L. Ott secretary, both of Fort Mill.

PEERLESS FOUNDRY CO., INC., Camden, N. J., care of the New Jersey Corporation Guarantee & Trust Co., 304 Market St., Camden, representative; iron, steel and other metal castings; $50,000.

THE SHELLOID CO., Providence, R. I.; special paints, etc.; $200,000. Incorporators: William A. and Fred Stang, and William A. Millard, 920 Park Ave., Providence. The last noted is representative.

WILL-NEW PRODUCTS CO., 1554 North Dearborn St., Chicago, Ill.; cleansing compounds and affiliated products; $20,000. Incorporators: Louis T. Bassett, William E. Newlin and Norman W. Newlin.

SEABOARD FELDSPAR CO., Equitable Bldg., Baltimore, Md.; operate a mining and grinding plant for feldspar production. Joseph P. Rodgers, Gottlieb Stengel and Clarendon I. T. Gould.

SUPEROIL CO., care of the Corporation Trust Co. of America, du Pont Bldg., Wilmington, Del., representative; refined oil products; $100,000.

NEWTON-SAULS PAINT CO., Tampa, Fla.; paints, varnishes, etc.; $25,000. V. M. Newton is president, and O. E. Sauls secretary and treasurer, both of Tampa.

PEERLESS PRODUCTS CO., 727 Garfield Ave., Jersey City, N. J.; organized; chemicals and chemical byproducts. John A. Martin heads the company.

HAWKEYE GYPSUM PRODUCTS CO., Fort Dodge, Ia.; gypsum blocks and specialties; $40,000. Incorporators: John E. Gustin and John B. Hinks, both of Fort Dodge.

WOLVERINE OIL CO., Lansing, Mich.; oils, greases, petroleum products, etc.; $10,000. Incorporators: Roy W. Brown and Bruce J. Maguire, 2340 South Park St., Kalamazoo, Mich.

HICKEY LEATHER CO., Shrewsbury, Mass.; leather products; 200 shares of stock, no par value. William J. Hickey is president, and T. Frank Hickey, Shrewsbury, treasurer.

BROOKLYN FIBRE SYNDICATE, Brooklyn, N. Y.; fiber-board products; $100,000. Incorporators: W. P. and S. Wisser. Representative: L. Nadel, 998 Ave. L, Brooklyn.

PITTMAN-JONES TILE CO., INC., Orlando, Fla.; ceramic tile products; $25,000. W. S. Pittman is president, and Clarkson Jones secretary and treasurer, both of Orlando.

VIVATEX PROCESSES, INC., Lodi, N. J.; chemicals and chemical byproducts; 10,000 shares of stock, no par value. Incorporators: Augustus S. Houghton, Woolsey A. Shepard and F. M. Morrice, all of Lodi.

PRIME TANNING CO., Boston, Mass.; leather products; $180,000. Morris I. Kaplan, president; and Samuel Shapiro, 50 Crowninshield Rd., Brookline, Mass., treasurer.

S-J-S FOUNDRY CO., St. Louis, Mich.; iron and steel castings; $15,000. Incorporators: Emil J. and Oscar F. Swanson, and C. A. Jacobson, all of St. Louis, Mich.

DAMASCUS LUBRICANTS, INC., 4345 South Western Blvd., Chicago, Ill.; oils, greases, etc. Incorporators: Harry J. O'Rourke, R. S. Tuthill and Harold Beacom.

THOMAS A. ZIMMERMAN, INC., North Bergen, N. J.; chemicals and chemical compounds; $125,000. Incorporators: James Puno and Thomas A. Zimmerman, 1019 Bergenline Ave., North Bergen. The last noted is representative.

KETOID CO., care of the Corporation Trust Co. of America, du Pont Bldg., Wilmington, Del., representative; chemicals and chemical compounds; $100,000.

PYRO TALC CO., Boston, Mass.; talc and kindred products; $250,000. Charles P. King is president; A. D. Huntoon, vice-president; and Henry V. Whitaker, 104 Ward St., Newton Center, Mass., treasurer and representative.

---

## Industrial Notes

At a meeting of the CANADA LINSEED OIL MILLS, LTD., Montreal, Que., Edward Liersch was elected president, succeeding John Baillie, deceased. J. J. McGill has been elected vice-president; H. J. Liersch, secretary and J. O. Gravel, treasurer.

At a meeting of the HAZEL-ATLAS GLASS CO., Wheeling, W. Va., J. H. McNash, heretofore secretary, was elected executive vice-president and general manager to succeed George C. Oliver, deceased. A. M. Elgeo, superintendent at Hazel No. 1 plant, Washington, Pa., has been appointed district manager of the Pennsylvania plants of the company. H. S. Brady, heretofore in charge of the Wheeling plant, has been appointed district manager in charge of West Virginia plants. S. B. Bowman has been appointed district manager for company plants in Ohio and Oklahoma.

THE ROBERT JUNE ENGINEERING MANAGEMENT CORP., of Detroit, which handles industrial advertising, sales development and engineering management, is moving from its present address at 8938 Linwood Ave. to 8836 Linwood Ave.

THE DeLAVAL STEAM TURBINE CO., Trenton, N. J., announces the formation of a Pacific coast sales organization covering the states of California, Oregon and Washington and parts of the adjoining states under the direction of William Pullen, with offices in Los Angeles, San Francisco and Seattle. The Los Angeles district office at 312 Union Oil Bldg., 617 West Seventh St., is in charge of Ivan E. Goodner. The San Francisco office, at 531 Rialto Bldg., Mission and New Montgomery Sts., is in charge of Mr. Pullen, assisted by Eck Baughn and Charles P. Markley. The Northwestern district office at Seattle, Wash., is located at 1306-7 L. C. Smith Bldg. and is in charge of James Q. Osborne, assisted by F. A. Hurlbut.